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GEOMAGNETIC FIELD IN QUATERNARY

Report on Activities of the Working Group of the Project II-2 Commission of the Academies of Sciences of the Socialist Countries for Planetary and Geophysical Research (KAPG)

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PREFACE

In the present stage of investigations of the geomagnetic field questions of the fine structure are of particular importance. For characterizing the geomagnetic field of any epoch it is essentially not only to determine the mean position of the virtual geomagnetic poles and the mean intensity of the field but also to explain the distribution of excursions, to determine the spectrum of secular variations and to analyse the transition regime of inversions occuring within the investigated time interval.

Frome the elements of the fine structure the processes of the course of inversions are best investigated. The main peculiarities of the transition regime of the Cainozoic inversions can be seen to be established. A main complication of the investigation of secular variations is the determination of their periods. The incompleteness of dating methods, among them the physical ones, don't allow to determine the periods exactly. Within the margin of dating errors sometimes is is necessary to select a combination of periods analysed by archaeomagnetic methods. As for excursions this phenomenon isn't described exactly up till now.

Investigating the fine structure of the geomagnetic field the scientist has to answer a series of questions and without their resolution it is impossible to install a real concept about the peculiarities of the field.

There is to add, that in the layers of sedimentary rocks - and even they are the carrier of information about the fine structure of the geomagnetic field - there are hiatuses, erosion gaps and changes in sedimentation rate, and for their recognition we did not succeed up till now.

When centering the attention of the participants of the present investigation within the frame of the Commission of the Academies of Sciences of the Socialist Countries for Planetary and Geophysical Research (KAPG) has concentrated first of all on excursions we hoped to increase the reliability of the results by combining various concepts and methods applied in the different laboratories.

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CHANGES IN THE GEOMAGNETIC FIELD AND CLIMATE

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Changes in the geomagnetic field as well as in the climate include a relatively broad spectrum of periods starting with hundreds of millions years up to the fluctuations with several years periods. Let us try to discuss the main of them and to contribute to the explanation of their causes.

Long-Term Fluctuations

It is known that during the Phanerozoic only four times the continents were repeatedly glaciated. It was between 800-600 million years ago (Precambrian - Cambrian), 450 - 410 million (Silurian), 320 - 250 million (Carboniferous - Permian) and during the past 10 million years. The most probable cause taken into account is the continental drift, the main characteristics of which can be explained by the model of the dynamic system of the world-wide plate tectonics and of its developments [1]. The distribution of continents in the subsequent geological periods investigated by paleomagnetic methods agrees well with palaeontological facts about the occurrence of warm climate (when nearly all continents were either on the equator or close to it, e.g. in the Ordovician) and about the glaciations (when several continents were close to the pole, e.g. in the lower Cambrian and Carboniferous - Permian) [1,2].

Long-term climate changes are caused according to the astronomical theory by the variations in the geometry of the Earth's orbit including the dominant cycle of 100 thousand years due to variations in eccentricity, the cycle of 41 thousand years corresponding to axial tilt and 21 thousand years (precession) [3].

Several researches believe that all these astronomical perturbations can induce such changes in monthly insolation which can cause also largest and most abrupt climatic changes including glaciations. The question however, remains why the present day climatic changes, especially abrupt coolings and warmings cannot be explained as due to insolation although they can even be higher (up to ± 30^{o}C) than they were in the past. This indicates that insolation is not efficient enough and, moreover, no convincing statistical links were found.

According to our results we can judge [4 - 7] that the changes in the Earth's orbital geometry have an effect on the processes in the Earth's core on the core-mantle boundary. Most probably the Earth's core has a different period of precession compared to that of the mantle. This is reflected in the changes of the geomagnetic field including changes of the geomagnetic poles and reversals of polarity. The spectral analysis of paleomagnetic data from the Stirone river showed periods 100, 140 and 20 - 30 thousand years [7].

The changes in the position of the geomagnetic pole as a centre of the auroral oval can significantly influence the long-term climatic changes including the alternation of glacial and interglacial periods. The processes occuring in the auroral oval seem to have an effect on the types of atmospheric circulation and on the weather changes. During the last period of claciation the geomagnetic pole was located in the Pacific and meridional circulation prevailed in Europe and North America at that time.

As we showed [4 - 7] the geomagnetic pole centre of the auroral oval moved from the Pacific to the eastern part of North America in the interval of 12 to 10 thousand years ago when also the last period of glaciation terminated. The auroral oval moved towards Europe too. The processes in the auroral oval at the time of increased corpus-

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cular radiation led to the zonalization of atmospheric circulation connected with the increase of temperature in Europe and in the eastern part of North America and the integlacial period occurred.

For the time interval of the past 20 thousand years, more precise palaeomagnetic results were obtained, showing for three territories on the Northern Hemisphere that the geomagnetic pole was located several times in the Pacific during the interval 18-12 thousand years ago [3, 4, 6, 7] (Fig.1). Also the intensity of the geomagnetic field was described. This pole moved from the Pacific to the eastern part of North America in the interval of 12 to 10 thousand years ago when also the last period of glaciation terminated.

This correlation seems to provide one possibility of explaining the alternation of glacial and interglacial periods. But it does not answer the question what is the role of the geomagnetic pole whether there is any and what is the physical mechanism leading to such expressive changes in temperature between glacial and interglacial periods.

The next spectrum of climatic changes includes 1000 - 600 years. The approximate position and wandering of the virtual geomagnetic pole between 200 B.C. and the present as well as variations of the geomagnetic inclination in the Caucasus and Bulgaria between 1,200 B.C. and the present closely indicate that the approach of the geomagnetic pole in the direction to Europe and the dip maxima are practically identical with the temperature maxima and vice versa [3, 7].

If we want to understand the changes in the past, we must be able to explain day climatic and weather changes, which are documented in the more reliable direct observations that the long-term changes in the past represented by sporadic and indirect data only.

In addition to the above-mentioned effects there is another factor-solar activity - which seems to influence climatic changes as well as fluctuations of weather [1, 2, 4-7]. Changes in geomagnetic activity, solar activity - R numbers- and in temperature defined by changes in the distribution of Alpine glaciers show periods of 200-250 and 450-600 years which are chronologically synchronous with orbital variables of the planets and the sun. In addition to it, the periods of 80 and mainly 22 and 11 years occur in the changes of geomagnetic activity, in temperature and in agricultural production in Europe (see Fig.2), [7].

Thus both long-term fluctuations of climate and weather proved to have very similar causes [4-7].

At extratropical latitudes in every season there are basically two types of atmospheric circulation [8]: the meridional type with blocking pressure highs over the Atlantic, but also over the eastern Pacific, extending northwards, and pressure lows extending from the polar region (l.h.s. of Fig. 3), and the zonal type with a central cyclone over the polar region (r.h.s. of Fig.3), with one type changing to the other many times in the course of the year. Two examples are given in Figs. 4a,b. We know that the temperature difference, which we observe when the meridional flow changes into zonal, is quite appreciable in some regions; the increase in temperature due to the zonal flow from the southern Atlantic may amount to as much as 30°C in Europe. At the same time cold air comes to the western part of North America. The abrupt decrease of temperature when corpuscular radiation is low occurs due to a sudden invasion of arctic air and may be as much as 30°C in Europe and in the east of North America. Simultaneously, the warm air from the Pacific comes to the western part of North America where we observe increased temperatures as was proved mainly for winter periods (Fig.2).

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Short-Term Changes

The general circulation of the atmosphere has been defined as the description and explanation of the large-scale behaviour of the atmosphere transforming the potential energy represented by the heat differences into kinetic energy of the mean motion.

Direct meridional circulation would take place on the longitudinally uniform non-rotating Earth due to the exchange of warm and cold air between equatorial and polar areas [8].

The effect of the Earth's rotation is to call Coriolis forces into play. Thus the air particles at upper levels, which began to move poleward under the influence of the meridional pressure force, now experience a deflecting force to the east. As a eastward velocity component develops, an equatorward Coriolis force sets in, and this tends to counteract the initial poleward pressure force. Thus the Coriolis force serves an important function of establishing zonal flow on the globe. Due to the orographic effect the meridional flow occurs, however, mainly in thenorthern hemisphere.

According to Namias [9] high index cycle represents a state of the general circulation with strong westerlies in mid-latitudes and weak meridional flow. This leads to weak meridional heat transport in mid-latitudes. Thus strong meridional temperature gradients develop across mid-latitudes. When this gradient exceeds some critical value, meridional flow begins to increase rapidly with time (Fig. 3a).

As new temperature contrasts develop and intensity near latitude 60° a zonal flow begins to increase again. This could imply an impression, that this process is spontaneous and that it is a property of the closed atmosphere. However the duration of individual cycles (occupying normally a period of 4 to 6 weeks but including cycles sufficiently long to account for glacial-interglacial cycles ice-ages) represents too large time-span and therefore it could not be used for any forecasts. Further it is known that the zonal flow steadily prevails on the southern hemisphere, while periods either with zonal or meridional flow alternatively occur on the northern hemisphere. The main reason for it are differences in the orographic effect due to continents and oceans. This can expressively influence the flow to such degree that we should consider the meridional flow with atmospheric blocking (Fig. 3a) to be basic in middle latitudes of the northern hemisphere due to orography and not the zonal flow as was considered till now. During several winter periods (e.g. 1962-65) the meridional circulation with expressive blocking high pressure areas prevailed on the northern hemisphere. It remains to answer the question why the zonal flow with a high index cycle can persist during some other winter periods (e.g. 1959, 1960, 1974, 1975, 1982).when the continents do not change their positions and the altitudes of mountains are the same and influence the atmospheric circulation in the same way as in case of occurrence of the meridional flow.

Our results indicate [4-7] that the reason for this peculiar behaviour of the atmospheric circulation are the processes which take place along the auroral oval at the time of enhanced corpuscular (geomagnetic) activity characterized by the penetration of energetic particles and bremsstrahlung as far as the lower stratosphere [9], resulting in direct increases of temperature and pressure even in the troposphere, and causing the zonalization of atmospheric flow to increase [6, 7]. Let us try to prove this statement.

Relatively unstable active regions, particularly variable filaments, occur at the solar disk centre prior to the enhancement of geomagnetic activity [4-6].

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The solar-energy flux for meteorological phenomena is

$$P_{EM} = \pi r_E^2 F\,(1-A) = 8.9 \times 10^{16}\,W$$

(if we assume the Earth to have an albedo $A = 0.5$, r_E is the radius of the Earth, F is solar constant). The available corpuscular energy flux is less than one millionth that of the solar electromagnetic energy flux absorbed by the Earth [10].

For the winter hemisphere, however, P_{EM} might drop to 6×10^{15} W. During an intense magnetic storm, the corpuscular energy flux could increase to $P_{c\,(max)} = 10^{12}-10^{14}$ W, which might be enough to use this energy as a trigger. Thus there appears to be enough power within the magnetosphere to cause such changes in the vorticity of the lower atmosphere if the power can be directed and coupled effectively.

In order to prove that meridional flow changes to zonal as a result of penetrating electrons and bremsstrahlung, leading to an increase in temperature and pressure even in the troposphere, we determined the average pressure values read at 12 points along the auroral oval (Fig.5). Here, the consequences of pressure effects are most pronounced after the heating in the higher layers of the atmosphere, being directly reflected in the troposphere in the change of the meridional type of atmospheric circulation into zonal (Fig.3). It is known [6, 7] that very pronounced meteorological changes, occurring as a result of Rossby's waves, obscure with their much larger amplitudes the said effect which can, however, be immediately observed at nearly all points (a pressure increase of 4-8 hPa). In an effort to prove that enhanced geomagnetic activity, indicating enhancement of corpuscular radiation, leads to an increase of atmospheric pressure and temperature along the auroral oval and to a change of meridional flow into zonal, we calculated the correlation coefficient between geomagnetic activity (Kp-indices) and the average values of atmospheric pressure first derived for 12 points at the 500 hPa level, for the period of September to December 1977. The correlation coefficient equal to 0.643 proves that this correlation is relatively good (Fig.5).

After the temperature and pressure have increased around the auroral oval, the cyclogenesis intensifies at sea level during the following days and the pressure lows that are generated move to the north, towards the geomagnetic pole as the centre of the auroral oval; this leads to a pronounced secondary warming (as much as 30°C) along the inside of the auroral oval with a time lag of 2-4 days after the increase of geomagnetic activity, as a result of warm air penetrating from the Atlantic and Pacific to the north (correlation coefficient 0.65). A low is created in the region of the pole and this leads, on the one hand, to the occurrence of sudden stratospheric warmings and to the intensification of the flow from the above-mentioned polar cyclone due south, between Canada and Greenland, across the Atlantic and into Europe, on the other hand [5-7]. The warm air from the Caribbean, which proceeds along the east coast to North America to the north during low geomagnetic activity, is deflected to the east by the flow from the Davis Straits proceeding south over the Atlantic once the geomagnetic activity has increased, and together they proceed along the parallels across the Atlantic towards Europe [5-7].

With a time lag of 13-20 days relative to the commencement of the geomagnetic storm, depending on the rate at which the meteorological processes involved proceed, a pronounced increase in temperature and precipitation occurs in Europe and North America due to the enhanced zonal flow. When the corpuscular radiation displays a marked decrease, meridional flow increases in intensity again and with the same time lag

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relative to this decrease Arctic air penetrates into Europe and North America (Fig.4a top), where this is then reflected in an abrupt and pronounced drop in temperature. We may refer to these intervals as "short glaciation periods in the present" because they cover practically the same regions which were subjected to glaciation during the last glacial period [6, 7] as the distribution of temperature deviations from normal, (Fig.9 in [7]) shows. Under very low geomagnetic activity the processes in the auroral oval are very weak, meridional flow, carrying cold Arctic air from the north Europe and North America, being prevelant in the northern hemisphere.

One of the most expressive features of anomalous climatic changes occurs in the equatorial eastern Pacific where the sea surface temperature can reach substantially above normal values. It defines the El Niño-Southern Oscillation (ENSO) phenomenon which goes through aperiodic oscillations of roughly 2 to 7 years [11] and whose strength was exceptional in 1982-83 (Fig.6c). The anomaly of the pressure difference between Tahiti and Darwin has been used as an index of the SO. Usually when this index is below normal then the sea surface temperature off the coast of South America (Peru) is substantially above normal, and is a disaster for the Peruvian fishery [11]. Big floods occur in Ecuador and Peru. SO is considered to be a cause of fluctuations of the global climate system.

If we want to prove the role corpuscular (geomagnetic) activity in the climate and weather changes we have to know how to explain all types of anomalous climatic fluctuations not only in Europe but also in global scale including the causes of the SO which is the second greatest climatic variation (the annual cycle being the largest).

Fig. 6 shows relations between the increase of geomagnetic activity (curve a) and the increase of the SO (curve b) usually anteceding the occurence of El Nino. The decrease of the geomagnetic activity corresponds to the decrease of the SO - at the same time increased sea surface temperatures of waters in the eastern Pacific (El Nino) occur - see the curve c. These connections can be explained as follows:

Under enhanced geomagnetic activity, especially in fall (see e.g. fall 1974, 1982), zonal flow in the northern hemisphere intensifies considerably, contraction of polar vortex, as well as intensified flow along the southern side of the mighty Pacific high take place and cause the easterly trade winds in low latitudes to strenghten. These winds drive the ocean circulation from the central (equatorial) Pacific westward to Australia. That is why sea level is about 40 cm higher in the western Pacific than the eastern Pacific coast line. The pressure difference between Tahiti and Darwin is positive at that time (high index of the SO).

When the corpuscular (geomagnetic) activity displays a marked decrease, meridional flow increases in intensity and helps to create West Canadian, Azores and East Siberian high pressure areas (Fig.3b) blocking the zonal flow. That is why the Aleutian low pressure area in winter depends still more expressively, moves southward and along its southern side the eastward flow intensifies. At the same time East Canadian and European low pressure areas develop as l.h.s. of Fig.3 and winter teleconnections [12] show. This causes the easterly winds in the western equatorial Pacific to diminish under low geomagnetic activity, and even to change the direction, blowing from west to east (see e.g. January 1977 and January 1983). The pressure in the central Pacific (Tahiti) begins to drop and in Australia (Darwin) to increase. This results in major changes in the equatorial current system. Oceanographers suggest that a rather fast Kelvin wave moves eastward in the ocean to the South American coast and then is reflec-

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ted as a slow westward moving and laterally spreading Rossby wave. The combined effect is to create a much thicker mixed layer and warm ocean surface off Ecuador/Peru - the El Nino warm sea surface temperature (SST) anomaly.

The sequence of individual phenomena ensues clearly from Fig.5 which shows that the majority of El Nino/Southern Oscillation episodes since 1935 were anteceded by the increase of geomagnetic activity in spring and fall and increase of the SO index (about half a year ahead). The decrease of geomagnetic activity in summer is connected with the meridionalization of atmospheric circulation on the northern hemisphere due to the weakening of processes in the auroral oval; this stimulated the deepering of the Aleutian low and the strenghening of the West Canadian high pressure ridge. The consequence of these changes in atmospheric circulation on the northern hemisphere is the typical ENSO phase with falling SO index (pressure tends to be low in the Pacific (Tahiti) and rises over the Australian-Indonesian region). The reversed equatorial current system stimulates the expressive SST anomaly near the South American coast and later farther west (El Nino - Fig.6).

We have shown [1,2,4-7] that cold winters over Europe and eastern North America occur at the time of meridionalization of atmospheric circulation (Fig. 3,4) due to arctic outbreaks as a consequence of decreased corpuscular (geomagnetic) activity (Fig.7 a,b). While below-normal winters sometimes occur simultaneously over Europe and eastern North America (e.g. 1962-63), in other years the winter was much colder in North America (e.g. 1976-77, 1964-65) and in other years in Europe (1939-1942). What can be the cause of these differences? Very cold winters over eastern North America were anteceded by the successive decrease of corpuscular (geomagnetic) activity from spring to winter. This caused that the meridionalization of the atmospheric circulation (see Fig. 7a) started already in summer and increased during fall. In other words, according to Namias 12 the quasi-stationary long-wave pattern developed from the North Pacific eastward and this helped "lock-in" the anomalous pattern because seasonal forcing did not oppose the factors leading to the abnormal forcing. Thus, at the time of an extremely low corpuscular (geomagnetic) activity the summer deep through off the west coast and the downstream ridge over central North America (which led to drought) are favored in summer but are unlikely to hold these positions in fall. Then, in winter the ridge of high pressure over western North America was very pronounced and the polar front over the east was displaced far to the south by persistently recurrent arctic outbreaks (Fig. 7a). Why this is so was still an unsolved problem although it is a useful empirical tool in long--range forecasting. Similar but not as sharp temperature declines in the east of North America as in January 1977 occurred in the winters of 1957 and 1964.

We can show that the geomagnetic activity was relatively high in spring and in fall and decreased considerably in summer and in winter. This led to the above mentioned abnormal forcing (due to the change of the prevailing zonal type to the meridional type of circulation) with features given in Fig. 7a. Below-normal pressure values are observed around the auroral oval, above-normal values in the polar region.

In case of cold winters occuring simultaneously in Europe and eastern North America (e.g. 1954-55, 1962-63) we observe very expressive decrease of corpuscular (geomagnetic) activity between September-October (when it was high) and November-December (Fig. 7b). This causes that the zonal flow is very intensified due to the processes in the auroral oval; after the expressive decrease of corpuscular (geomagnetic) activity in November-December and after repeated alternation of an expressively increased (for 3-7 days) and decreased (for 5-10 days) activity recurrent arctic outbreaks are enabled across Scandinavia towards Europe because the quasi meridional flow is increasing as characterized

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by a meridionally extensive ridge over the east Atlantic. Between the Azores high and the Scandinavian low arctic air penetrates to Europe and leads to the expressive decrease in temperatures. In this way, the recurrent and expressive decrease of corpuscular (geomagnetic) activity stimulates the factors leading to the abnormal seasonal forcing not only above central North Americs (where usually high pressure area occurs in winter but also above central Europe which is usually under the influence of the Atlantic. Then we observe below-normal temperatures in winter both in eastern North America and Europe because the polar front was here displaced far to the south in both areas (Fig. 7b).

Above-normal winter temperatures over central Europe and eastern North America, e.g. 1949-1952, 1956-7, 1958-1962, 1971-1975, 1982-1984 occur at the time of enhanced corpuscular (geomagnetic) activity (Fig. 7c).

The enhanced cyclogenesis as a result of penetrating electrons increasing temperature in auroral oval intensifies the zonal flow which prevails over North America and Europe and eliminates external forcings such as orography: in other words arctic outbreaks over eastern North America and Europe to the south are suppressed by intensified westerlies at the time of enhanced corpuscular (geomagnetic) activity which is reflected in above-normal temperatures above both territories. Positive pressure departures from normal are observed around the autoral oval while they are negative in the polar region (Fig. 7c).

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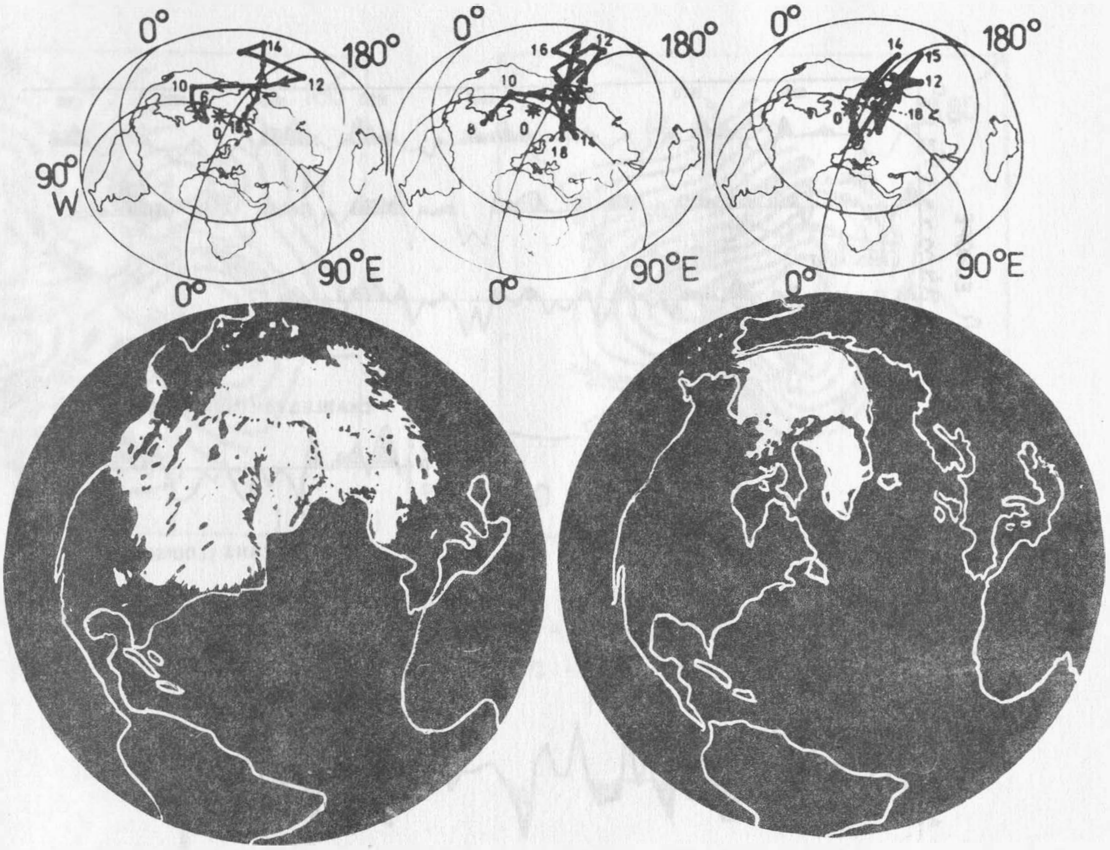

Fig. 1. Changes in the position of the geomagnetic pole over the last 18 000 years determined from palaeomagnetic investigations in Czechoslovakia (left top), in Japan (middle top), and in the U.S.A. (right top). The glaciation of the northern hemisphere during the last glacial period approximately 20 000 - 13 000 years ago (left bottom) and the present distribution of glaciers (right bottom)

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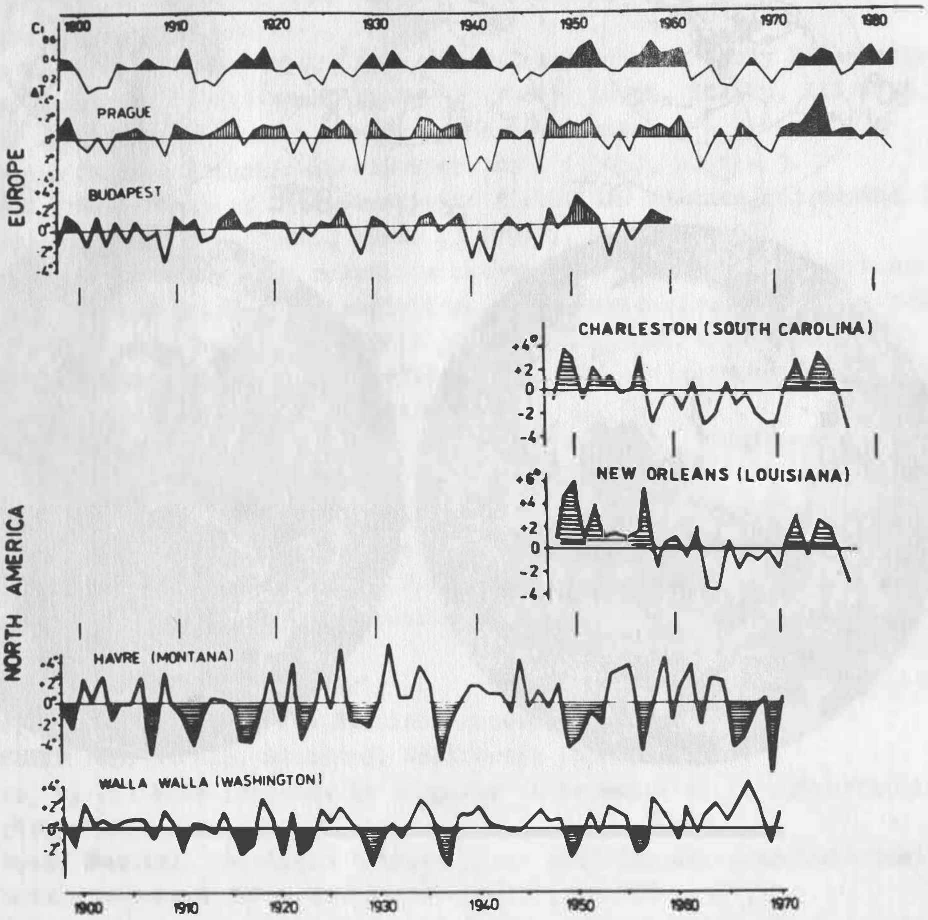

Fig. 2. Comparison of geomagnetic activity (C_i indices - averages for November, December, January, February) with the average temperature values-deviations from the normal in Europe (Prague, Budapest), in the Atlantic region of the U.S.A. (Charleston, New Orleans) and in the Pacific region of the U.S.A. (Havre, Walla-Walla). The positive correlation coefficient was obtained for C_i indices and temperature in Prague (+0.632 for the interval 1949 - 76) and the negative coefficient for Havre (-0.457 for the interval 1949 - 64). The deviations in Charleston and New Orleans have a similar character as in Prague and Budapest but opposite to Havre and Walla-Walla

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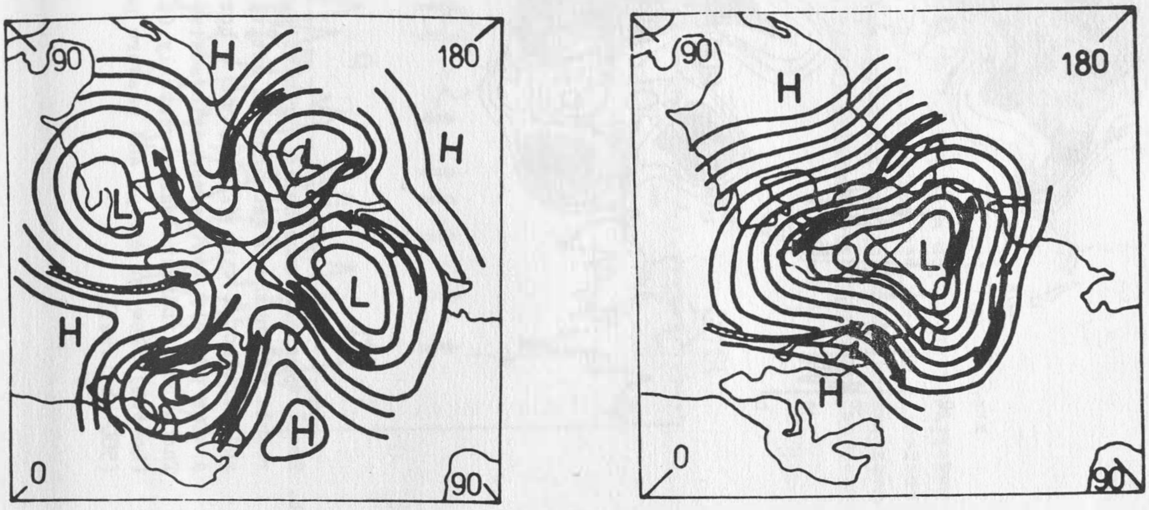

Fig. 3. Example of meridional (l.h.s.) and zonal (r.h.s.) type of atmospheric circulation shown on a 500 mb level map

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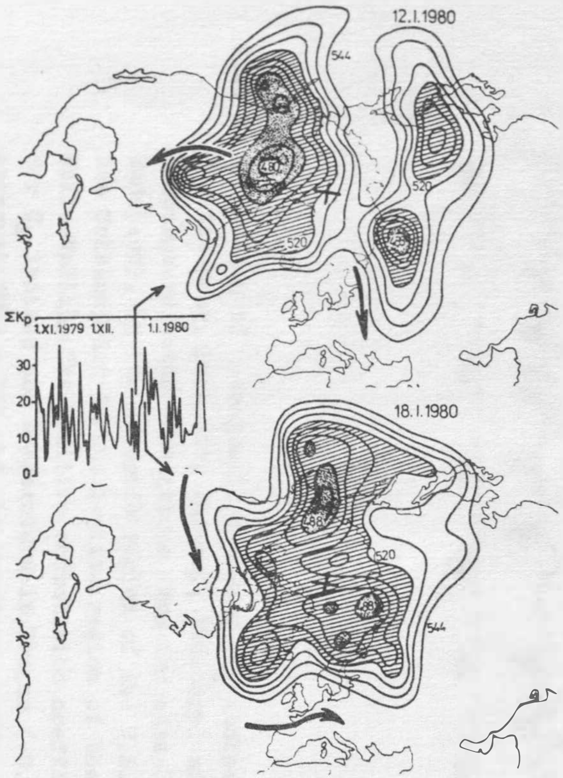

Fig. 4a. Meridional type of atmospheric circulation (12.1.1980 - top) as a result of decreased geomagnetic activity (on 22. to 25. 12. 1979) and zonal flow (18.1.1980 - bottom) which developed at a time of enhanced geomagnetic activity (on 29. to 31.12. 1979). The arrows indicate cold, Arctic (top) and warm, westerly (bottom) flow in Europe and eastern part of North America (500 mb level)

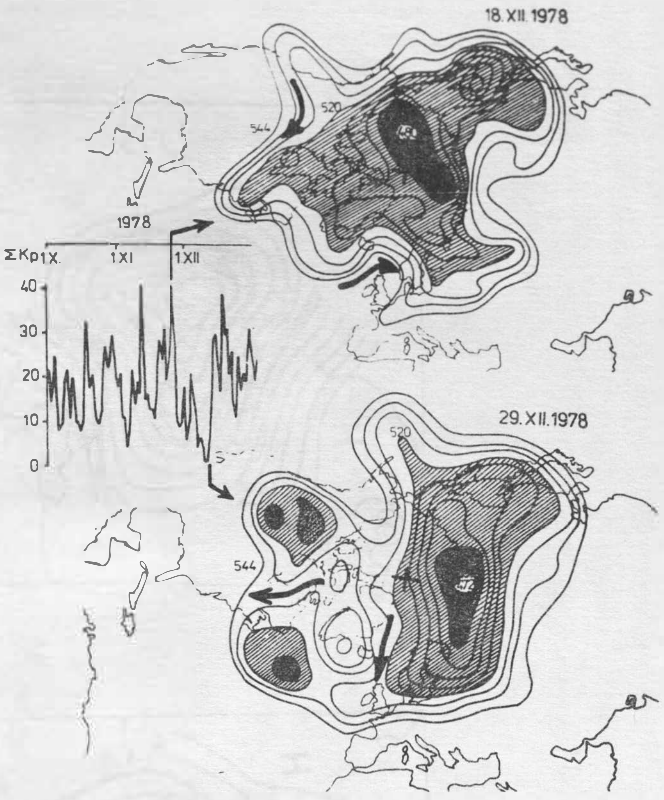

Fig. 4b. Zonal type of atmospheric circulation (18.12.1978 - top) as a result of enhanced geomagnetic activity (on 25. to 27.11.1978) and meridional type (29.12.1978 - bottom) which developed at a time of very low geomagnetic activity (on 10. to 12.12.1978). The arrows indicate warm, westerly (top) and cold, Arctic (bottom) flow in Europe and eastern part of North America (500 mb level)

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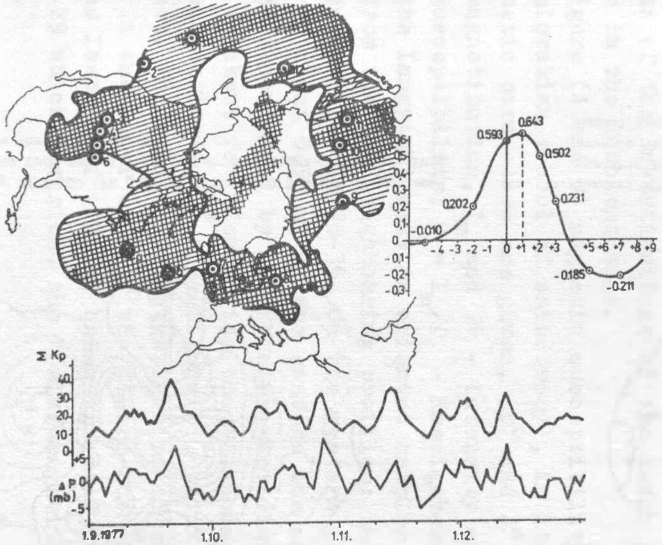

Fig. 5. Region of the auroral oval (hatched) in which the most pronounced increase of atmospheric pressure occured (500 mb level) at the time isolated geomagnetic storms occurred in the latter third of 1977. The values of pressure at points 1 - 12 were used to calculate the correlation coefficient between geomagnetic activity (ΣK_p) and deviations of pressure from the normal (r.h.s.). The graph of the changes of geomagnetic activity (ΣK_p - 3 daily moving averages) and pressure deviations (averages from points 1 - 12) given at the bottom of the figure indicates for zero time lag the correlation coefficient equal to 0.643

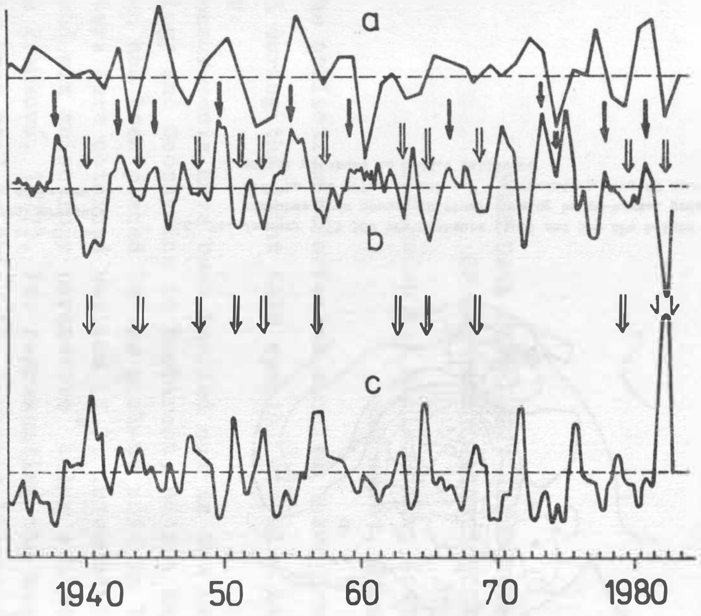

Fig. 6. Changes in geomagnetic activity (curve a) and in Southern Oscillation (curve b) showing positive correlation while increased sea surface temperatures (El Nino - curve c) show negative correlation with curves a, b

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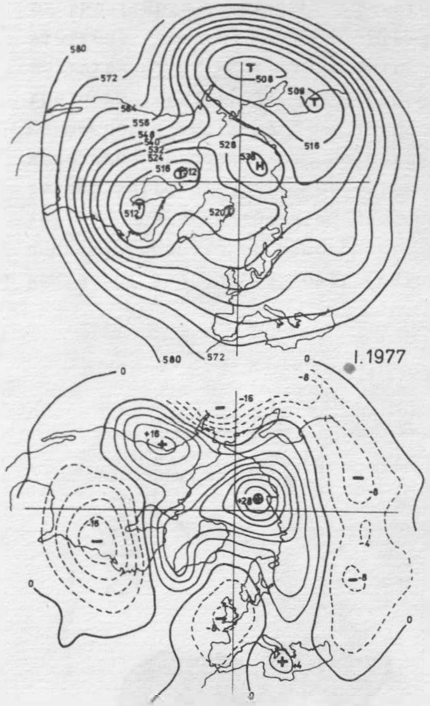

Fig. 7a. January 1977 500 hPa contours (top) and 500 hPa height departures from normal (bottom) showing above-normal pressure area in the polar region

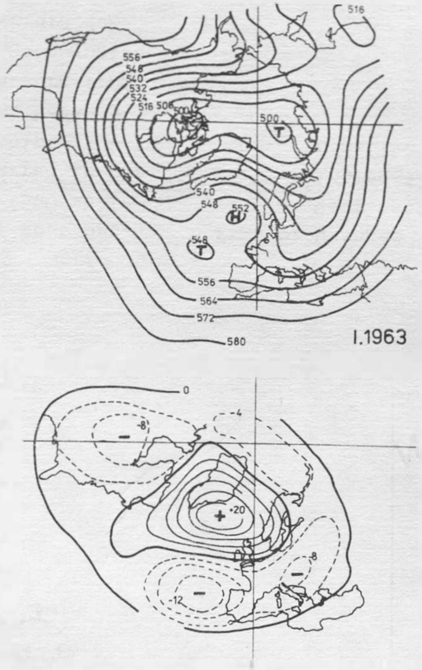

Fig. 7b. January 1963 500 hPa contours (top) and 500 hPa height departures from normal (bottom) showing above-normal pressure area in thepolar region, and a surrounding ring of below-normal pressure in middle latitudes

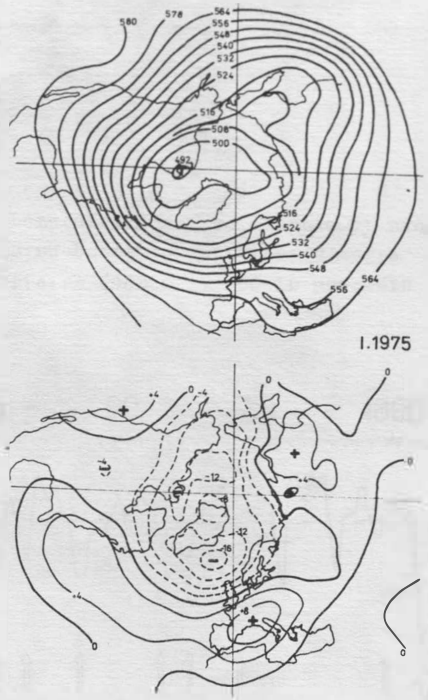

Fig. 7c. January 1975 500 hPa contours (top) and 500 hPa height departures from normal (bottom) showing below-normal pressure area in the polar region and a surrounding ring of above-normal pressure in middle latitudes

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SOME DATA CONCERNING ANISOTROPY OF MAGNETIC SUSCEPTIBILITY OF THE PALAEOMAGNETICALLY INVESTIGATED LOESSES

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The collection of oriented samples taken from the sections palaeomagnetically investigated during the joint KAPG specialists also in respect of magnetic susceptibility anisotropy.

Measurements have been carried out in the Laboratory of paleomagnetism of Institute of Geology and Geophysics in Bucharest, with a Kappabridge KLY-1 (Jelinek, 1973), The specimen has been placed in the pick-up unit in 15 positions; principal susceptibilities parameters were obtained maximum (K_1), intermediate (k_2) and minimum (k_3), their directions and six anisotropy parameters[*] being evaluated by using the program ANISO lo (Jelinek and Franková, 1977). For representing the magnetic fabric the magnetic anisotropy plot has been used in which the magnetic lineation is taken as ordinate and the magnetic foliation F as abscissa (Hrouda and Janák, 1976), the image representing the shape of the susceptibility ellipsoid. The orientation of principal susceptibility parameters have been represented on the lower hemisphere of an equal-area projection (k_1 - ▲ , k_2 - ■ , k_3 - ●). For investigating the dependence of the changes in shape of the susceptibility ellipsoids on the degree of magnetic anisotropy, the F/P plot has also been used, the magnetic foliation F being taken as ordinate and the degree of anisotropy P as abscissa (Hrouda and Janák, 1976).

It is the Iangyiul' section that is taken as an example in this paper concerning the results of the investigations of the teams participating in the KAPG palaeomagnetic expedition in the Tashkent zone.

In figure (A and C) magnetic susceptibility anisotropy data are (after the model of Czechoslovakian school of anisotropy), in its central part (B) the variation of the palaeomagnetic parameters are given, (D^o and J^o - declination, inclination of primary remanent magnetization, I_n and $\varkappa$ - intensity of natural remanent magnetization and magnetic susceptibility; $Q = I_n/I_i$ - Koenigsberger ratio).

For the Iangyiul' section oriented samples have been collected (by the "classical method") from the two neighbouring profiles: the western one - sample UZ 17-27 and the eastern one, samples UZ 28-35. On the western profile the samples have been taken at intervals of about 0,50 m, on the eastern one collecting was continuous in the limits of the zone recommended by the palaeomagnetician researches from the Institute of Seismology in Tashkent for identifying the palaeomagnetic anomaly. The data obtained after thermal demagnetization[**] (see figure B), point out a "palaeomagnetic anomaly" in the central part. The results of investigation of magnetic susceptibility anisotropy are presented in the upper half of the figure for the two profiles W and E (fig. A1 and A2), in its lower half (fig.C) being situated the anisotropy data provided only by samples UZ 28-29 which described the "palaeomagnetic anomaly" (isolated by dashed line in figure B).

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[*] In the present comment three anisotropy factors have been taken into consideration: magnetic lineation ($L=k_1/k_2$), magnetic foliation ($F=k_2/k_3$) and the degree of anisotropy ($P=k_1/k_2$) - see Hrouda (1982).

[**] The magnetic thermowashing has been made with a TSD-1 Schönstedt thermal specimen demagnetizer.

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The orientation of the directions of the principal susceptibilities indicates for the two profiles W and E (fig. A1, A2) that the magnetic foliation is practically horizontal, the minimum susceptibilities (situated practically vertically) having the orientation perpendicular to the bedding (the position of the Pleistocene loesses sampled in the Iangyiul' section has been considered to be horizontal), confirming that the ferromagnetic grains are oriented parallelly to the bedding plane.

The magnetic anisotropy plot L/F indicates for both profiles W and E (fig. A1, A2) that most susceptibility ellipsoids are predominantly oblate, the majority of plots being situated into the field of flattening. As for relation between the parameters F and P, the latter showing a slight degree of anisotropy ($P < 4,5\%$), an increase in the F values is noticed, accompanied by an increase in the degree of anisotropy P. In order to evaluate objectively the measure of dependence between these two parameters, in quantitative terms, the correlation coefficient was calculated: it is equal to $r = 0,799$, which proves that the measure of dependence between the F- and P- parameters is high. The correlation is better defined in the sitiation of profile E (fig. A2), where the number of samples collected continuously from the interval of interest of the Iangyiul' section was greater. The measure of dependence between the F- and P- parameters is very high ($r = 0,940$).

As to the rock samples selected from the level where the "palaeomagnetic anomaly" has been identified (UZ 28-29), it can be noticed (see fig. C) that the data of the magnetic susceptibility anisotropy associated only to this set of samples which have the same characteristics as the whole palaeomagnetic collection from the Iangyiul' section:

- horizontal magnetic foliation, with the orientation of minimum susceptibilities in practically vertical direction (perpendicular to bedding);
- most susceptibility ellipsoids are predominantly oblate, the majority of plots being situated in the field of flattening;
- the very good correlation of parameters F and P is maintained, the degree of anisotropy ranging between limits characterizing the whole section ($P < 4,5\%$); the correlation between these two parameters is very high: $r = 0,952$).

Taking all this into account we think we can consider that in the situation of the loesses in the Iangyiul' section, the magnetic anisotropy did not influence the direction of the vector of remanent magnetization, the "palaeomagnetic anomaly" identified, possibly representing, at least in this respect, an anomaly of the direction of the ancient magnetic field of the Earth. Of course, for this hypothesis to be valid, for increasing the degree of certainty that the "palaeomagnetic anomaly" identified is geomagnetically controlled, some other factors should also be excluded (for instance, sedimentogenetic ones) that could determine "the recording" of the anomalous parameters of primary remanent magnetization by the Pleistocene loesses in the Iangyiul' section.

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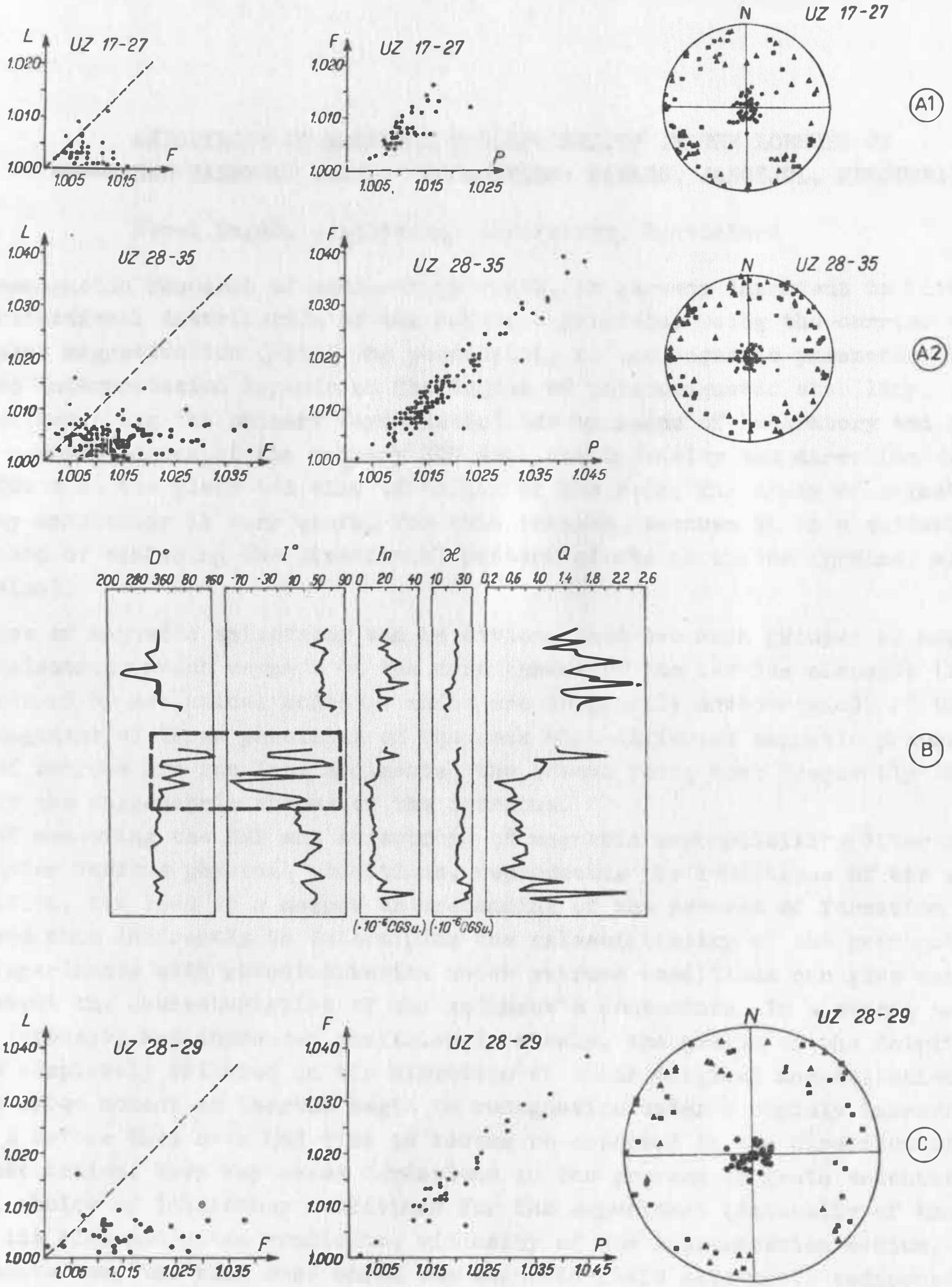

Fig. 1. Magnetic anisotropy and palaeomagnetic results obtained from the loess in the Iangiyul' section

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ANISOTROPY OF MAGNETIC SUSCEPTIBILITY IN THE LOESSES OF THE TASHKENT REGION (LOCALITIES: KARASU, JANGIJUL, MINGTEPE)

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For palaeomagnetic research of sedimentary rocks, it is very important to know the spatial and directional distribution of the detritic particles being the carrier of the natural remanent magnetization (NRM). The possibility to use magnetic parameters for palaeomagnetic interpretation depends on the degree of palaeomagnetic stability, on the possibility of revealing the primary (syngenetic) RMP by means of laboratory and field tests and on correspondence of the primary NRM with the intensity and direction of the geomagnetic field at the place and time of origin of the rock. The study of magnetic susceptibility anisotropy is very useful for this problem, because it is a suitable and effective method of analysing the directional pattern of the particles (grains, minerals, magnetic domains).

The sources of magnetic anisotropy can be divided into two main groups: a) magnetocrystalline anisotropy which depends on the arrangement of the lattice elements (including changes caused by mechanical stresses which are frequently anisotropic), b) the anisotropic arrangement of large particles of the rock with different magnetic properties. Both groups of sources are run into sediments, the second being most frequently the dominant, namely the anisometric shapes of the detritus.

The results of measuring the RMP and anisotropy of magnetic susceptibility after resedimentation under various physical conditions, reproducing the conditions of the original sedimentation, can lead to a deeper understanding of the process of formation of the primary RMP and thus indirectly to determining the palaeointensity of the geomagnetic field. Also experiments with resedimentation under extreme conditions can give useful information about the characteristics of the sediment's components. In a strong magnetic field, which intensity has increased sufficiently slowly, the grains of the detritus become nearly completely oriented in the direction of their original magnetization. Grains with a large moment of inertia begin to remagnetize under a rapidly increasing magnetic field before they have had time to become re-oriented in the direction of the original magnetization; they may cause deviations in the process of grain orientation.

A careful choice of laboratory conditions for the experiment (intensity of the magnetic field, its time and space gradients, viscosity of the sedimentation medium, the rate of sedimentation, the time over which the magnetic field acts until sedimentation is concluded, conditions of consolidation and compaction of the laboratory sediments etc.) provides the possibility of penetrating deeper into the essence of the phenomena, to discover more precise relations and parameters of the internal magnetic structure of the rock. The largest deficiency of these experiments is the impossibility of reproduction of natural processes over periods acceptable for laboratory investigations.

The loesses collected by the expedition of the KAPG Project 2 in Tashkent region in 1982, were created by the deposition of dust particles probably in a dry environment. It was necessary to determine the manifestations of magnetic susceptibility anisotropy and to determine the relations between its origin and the conditions of sedimentation. It was also possible to apply laboratory resedimentation under conditions which enable the experimental work to be accelerated (dry method). The sediment itself was weakly or very weakly consolidated which meant that the particles, after the rock had been disintegrated, would correspond sufficiently well to the particles of the original (unconsolidated

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natural detritus.

2. Results of measuring magnetic susceptibility anisotropy of the samples in their original condition.

The samples were collected by metal pipes driven in the horizontal plane in the direction chosen by the help of the compass. The samples thus obtained were prism-shaped, length 40 to 70 mm, of square cross-section 22 by 22 mm; after their surface had been cleaned, they were cut into 2 or 3 cubes with sides of 20 mm (series a, b and c). After NRM and RMP of the series a samples had been measured, following A.C. demagnetization maximum inductions of 5, 10, 15, 20 to 80 mT in steps of 10 mT, also the parameters of magnetic susceptibility anisotropy were determined using a KLY-2 bridge (produced by Geofyzika of Brno). In calculating the parameters of the magnetic anisotropy, the relations given by Jelínek /2/ were used. The individual values of the volume magnetic susceptibility have a natural scatter (see Table 1). The main parameters of the anisotropy of magnetic susceptibility of the separate samples are shown in Fig.1 and 2. Fig.1 shows the directions of the maximum and minimum susceptibility for each locality, the latter the parameters $P = k_1/k_3$, i.e. the degree of anisotropy, $E = k_2^2/k_1/k_3$ - the parameter of the shape of the susceptibility ellipsoid after Hrouda /1/, as well as the diagrams of the directions of the principal susceptibilities k_1 and k_3, the separate profiles at the localities being divided by depth into groups of 5 to 7 samples.

At the Karasu locality, the directions of the minimum magnetic susceptibility run mostly from N to S, which is surprising and cannot be explained. The axes of the maximum susceptibility show preference for the EW direction. This could be indicative of the direction of transport of the material, in this particular case probably to the west. The plastic deformation of samples prisms might have an effect on the magnetic anisotropy as well. The distribution of the parameters of the susceptibility anisotropy along the profile is roughly stabilized, the predominant orientation being planeparallel ($E > 1$). The degree of anisotropy is relatively low and varies between 1.005 and 1.02, in three cubes around 1.03 and in one it is 1.038.

At the Jangijul locality, the axes of maximum susceptibility run EW, the minimum susceptibility has scattered directions mostly from vertical to south. Although the separate groups have certain characteristic directions of minimum susceptibility, no distinct correlation could be found between parameters and directions of susceptibility anisotropy and the NRM and RMP vectors; this would support the opinion that a palaeomagnetically different layer (corresponding to the sections of the western part of profiles J2 and J3, and to the sections of the eastern part J7 and J8) is not related with evident change of the dynamic parameters in the process of sedimentation. A similar conclusion can also be made from analysing the data on the mean susceptibility $\bar{k}$ and NRM or RMP (20 mT), see Table 1. The correlation coefficients $r_{0/k}$ of corresponding parts of the profiles what may indicate certain consistence of the magnetic parameters in the horizontal direction; the considerable variability of the correlation coefficients of vertically consequence layers has no particularly significance in interpreting a small number of elements (5-7). For example, section J5 has a high negative coefficient r (-0.95, and -0.90) and, at first sight, it seems that a statistical explanation is simpler that a physical one.

The directions of maximum susceptibility of the samples at locality Mingtepe are in the horizontal plane with no further distinct differentiation. The minimum magnetic susceptibility mostly in the vertical direction corresponds to the assumed sedimentation model with low values of the velocity of the transport medium. At this locality the bottom two sections were sampled by cutting cubes from monolithic blocks, so that the samp-

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les were not affected by the deformation which may be expected in sampling with samples. After comparing the results from both parts of the profile, we can assume that the method of sampling with samplers is satisfactory with regard to preserving the measured magnetic parameters, at least in rocks of mechanical properties similar to those from this locality.

3. Results of measuring the anisotropy of magnetic susceptibility of the resedimented samples.

For a better understanding magnetic structure of the studied loesses the anisotropy of magnetic susceptibility and RMP of samples resedimented in laboratory fields were investigated. To begin with, the geomagnetic field ($B = 50\ \mu T$) and the induction between the pole-pieces of an electromagnet (square cross-section 60 by 60 mm, magnet gap 50 mm, $B = 200$ mT, current 15 A from a 12 V battery) were chosen. Eight samples were selected for the experiment (Karasu 3: K11A, K32A, K63A; Mingtepe 2: M13A, M21A; Jangijul 3: J27A, J37A, J85A) with distinctly defined parameters of magnetic anisotropy in the natural condition of the samples. After a check measurement of the directional susceptibilities, the samples were crushed (they disintegrated easily in their natural condition due to small consolidation) and resedimented. The reconsolidation remained problematic. To avoid the more tedious wet way, which did not correspond probably to the original process, full dry sedimentation was applied together with consolidation by pressure in the vertical direction. Under pressures of 10 to 100 MPa, samples were obtained with roughly the same density as those in the original condition, also the mechanical strength, required for handling the samples in measuring with the JR-4 and KLY-2 instruments, being renewed. After the first two resedimentations ($B = 50\ \mu T$ and $B = 200$ mT) two check resedimentation in the same order were made. Whereas the results of the measurements after the 1st and 3rd resedimentation displayed considerable difference in most samples (apparently due to the magnetization of particles by the strong field during the 2nd resedimentation), the 2nd and 4th resedimentations yielded a relatively good agreement of the RMP vectors, the directions of the maximal susceptibilities, but, as a rule, a district increase in the parameters P and E. Some interesting results are illustrated in Fig.3 for which the mean values of the 1st and 3rd, and the 2nd and 4th resedimentation were used. Although the original values of parameter P varied within a relatively small limit, the resedimented samples displayed distinct differences. Parameter E after resedimentation in a weak field, is always larger than 1 ($E > 1$) (the preferred planar-parallel orientation), whereas after resedimentation in the strong field a conspicuous linear parallelness occurred, probably caused by the high percentage of single-domain grains or multidomain grains with linear-parallelly arranged structure. The degree of parallelism ($\lambda = \Delta E/\Delta P$) decreases, on the average, from Karasu (0.7) to Jangijul (0.5) to Mingtepe (0.2). The degree of planeparallelism displays the same regularity under resedimentation in the weak field.

These results prove the distinct difference between the localities apparently due to the different internal magnetic structures of the loess particles, probably caused by the directional orientation of the domain in the particles. This arrangement, magnetic fabric, which is also dependent on the particle size, could have been generated at different times, when the parental rock originated, during weathering and, finally, also after sedimentation, which could have caused a certain differentiation in the internal magnetic structure.

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4. Conclusion

The measurements of magnetic susceptibility anisotropy in the samples of loesses from the Tashkent region have shown that they provide valuable information for a more detailed classification of these sediments and for a better understanding of their internal magnetic structure. The orientation of the ellipsoid of magnetic susceptibility displayed partly different characteristic features for the separate localities, or parts of the profile, and we can assume that it can be used to determine the direction of the transport flow.

The experiments with resedimentation under various magnetic fields have proved that the magnetic structures of the loess particles from various localities are differentiated and have underlined the perspectives for a more detailed development of the method of resedimentation controlled by the magnetic field, and for utilizing this method in studying the detritic RMP.

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Table 1

locality	n	$.10^{-6}$ SI		$.10^{-5}$ SI				correl.	coeff.
section		k	k	PMP_0	RMP	RMP_{20}	RMP	$r_{0/k}$	$r_{20/k}$
K 1	24	1006	209	421	123	244	71	0.35	0.16
K 2	25	981	172	422	190	185	132	-0.10	-0.24
Karasu	49	993	189	422	159	214	109	0.09	-0.06
J 1	7	547	33	353	124	237	90	0.73	0.53
J 2	7	491	35	278	106	191	85	0.28	0.32
J 3	5	481	35	146	45	79	35	-0.54	0.29
J 4	5	543	48	325	220	240	190	0.87	0.89
J 5	5	512	45	271	89	189	63	-0.95	-0.90
J 6	5	580	23	428	165	293	115	0.95	0.95
J 7	5	495	54	200	118	160	102	0.16	0.08
J 8	5	529	47	145	55	88	19	-0.50	-0.41
Jangijul	44	522	49	275	148	187	113	0.49	0.50
Mingtepe	21	469	41	286	107	177	69	0.06	-0.05

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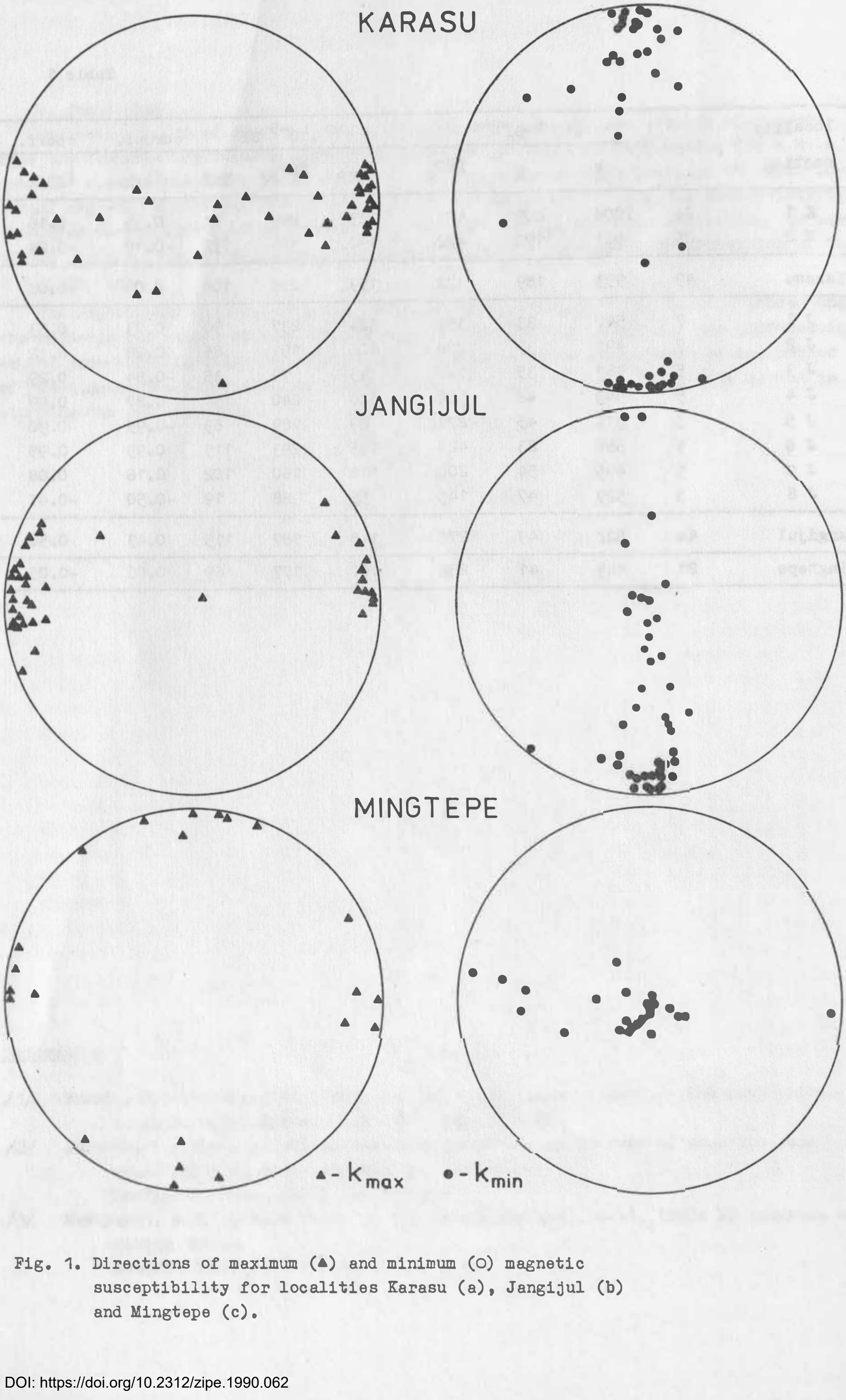

Fig. 1. Directions of maximum (▲) and minimum (○) magnetic susceptibility for localities Karasu (a), Jangijul (b) and Mingtepe (c).

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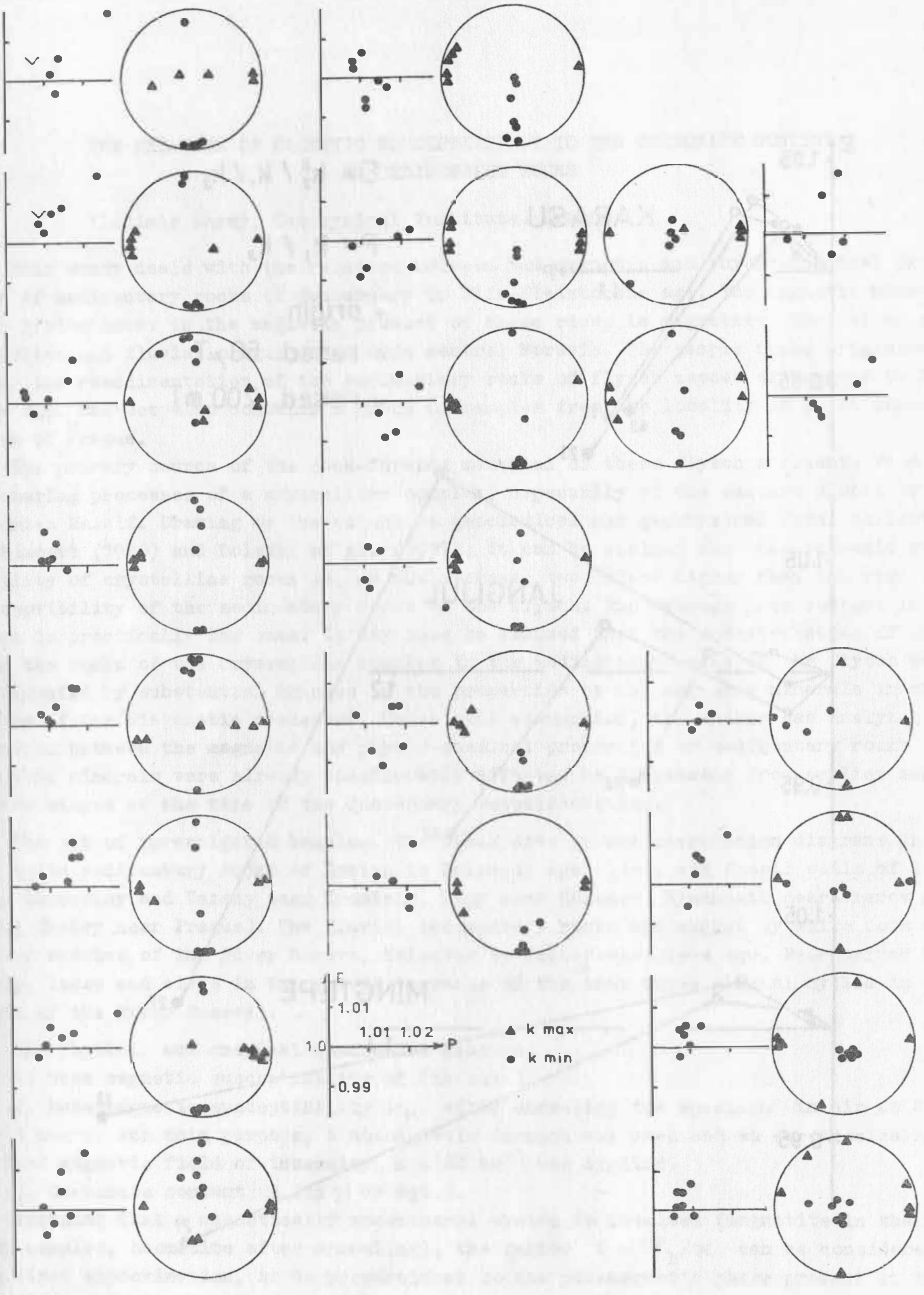

Fig. 2. Parameters of the anisotropy of magnetic susceptibility $P = k_1/k_3$, $E = k_2^2/k_1/k_3$ and directions of the extreme susceptibilities for profile sections at locality Karasu (left-hand side of diagram), Jangijul west (middle part), Jangijul east (right-hand upper part) and Mingtepe (right-hand lower part). ▲k_{max}; ○k_{min}.

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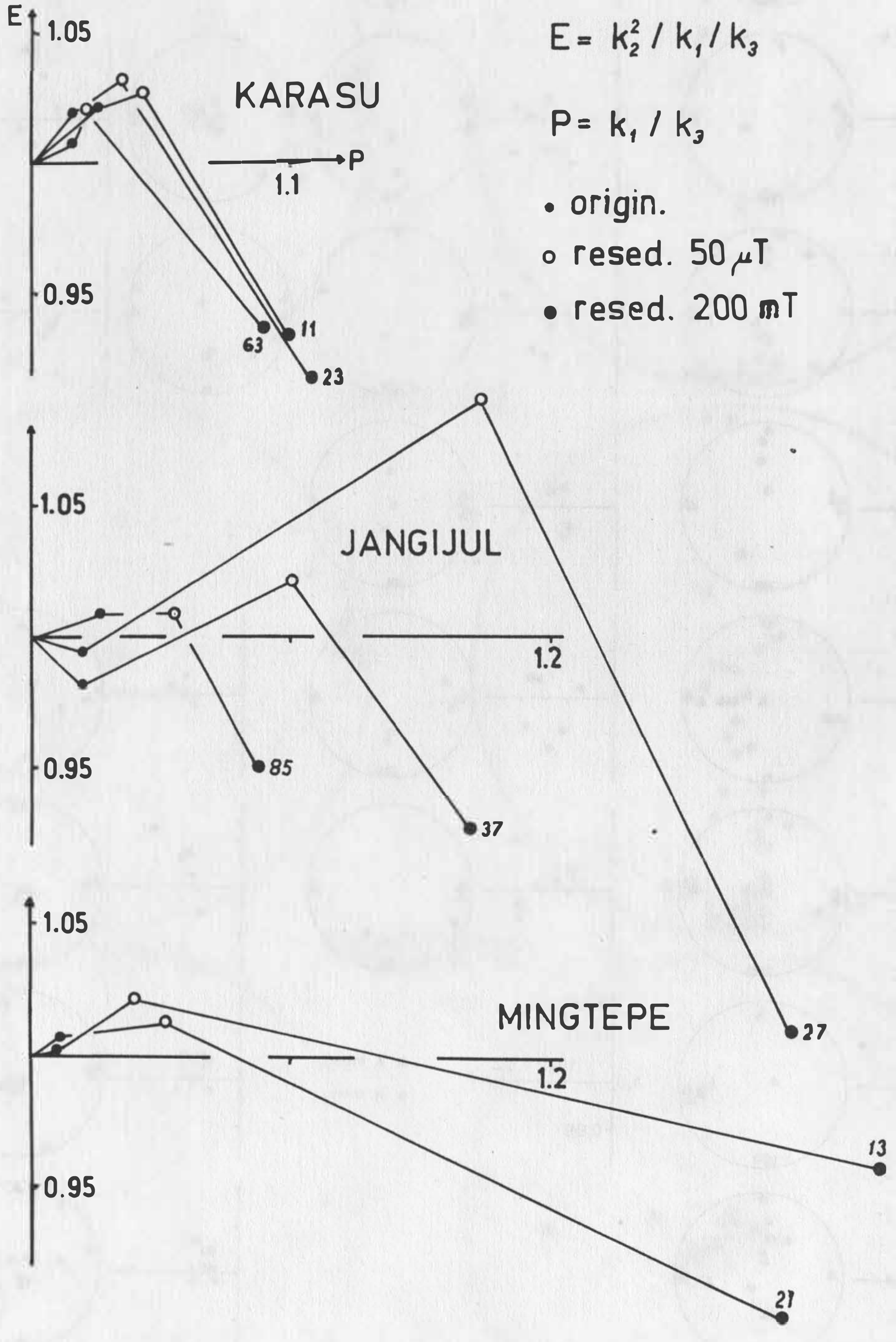

Fig. 3. Parameters of the anisotropy of magnetic susceptibility for samples selected from series a.
• – original sample; ○ – sample resedimented at B = 50 μT; ● – sample resedimented at B = 200 mT.

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THE RELATION OF MAGNETIC SUSCEPTIBILITY TO THE CARBONATE CONTENT IN SEDIMENTARY ROCKS

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This study deals with the relation between the magnetic and physic-chemical properties of sedimentary rocks of Quaternary to Plio-Pleistocene age. The magnetic mineral that predominates in the magnetic product of these rocks is magnetite. The set of samples of eolian and fluvial origin comes from central Moravia. The sample rocks originated mostly by the resedimentation of the sedimentary rocks of flysch nappes of Neogene to Palaeogene age. The set also contains a group of samples from the locality of Dolní Chabry, north of Prague.

The primary source of the rock-forming material of these flysch sediments were the weathering processes of a crystalline complex, especially of the eastern slopes of the Bohemian Massif. Drawing on the extensive geochemical and geophysical data, collected by Adamová (1980) and Dolezal et al. (1977), it can be claimed that the magnetic susceptibility of crystelline rocks is, on the average, two orders higher than the magnetic susceptibility of the sedimentary rocks of the flysch. The average iron content in both cases is practically the same. It may thus be assumed that the redistribution of the iron from the rocks of the crystalline complex in the sedimentary rocks of the flysch was accompanied by substantial changes in the properties of the magnetic minerals in the course of the diagenetic processes. Under this assumption, the author has analyzed the relation between the magnetic and physic-chemical properties of sedimentary rocks. Their magnetic minerals were already considerably affected by diagenesis from earlier sedimentation stages at the time of the Quaternary resedimentation.

The set of investigated samples. The black dots on the correlation diagrams indicate the eolin sedimentary rocks of Eemian to Holocene age (loess and fossil soils of localities Lutopecny and Vazany near Kromeriz, Zopy near Holesov, Predmosti near Prerov and Dolni Chabry near Prague). The fluvial sedimentary rocks are marked by white dots (the middle reaches of the River Morava, Holocene to Plio-Pleistocene age. Redeposited fossil loams, loess and clays in the gravel terraces of the last three glacial cycles in the basin of the River Rusavá).

The physical and chemical quantities measured

1. Mass magnetic susceptibility $\varkappa$ (in situ).
2. Mass magnetic susceptibility $\varkappa_h$ after annealing the specimen in air at 800°C for 3 hours. For this purpose, a nonmagnetic furnace was used and an electronically stabilized magnetic field of intensity $H = 80\ \mathrm{Am}^{-1}$ was applied.
3. Carbonate content A (in % by wgt.).

Assuming that a magnetically monomineral system is involved (magnetite in the in situ samples, haematite after annealing), the factor $D = \varkappa_h/\varkappa$ can be considered, in the first approximation, to be proportional to the paramagnetic phase present in the rock.

Correlation of the measured parameters, experiments and discussion.

By investigating the relation between $\varkappa$ and A in a set of more than 6000 specimens of sedimentary rocks of Quaternary to Palaeozoic age from various geological units in Czechoslovakia, the following boundary exponential was derived statistically:

$$\varkappa = 3.315\times10^{-7} \exp(-0.048\,A),\ A < 6,60>. \qquad (1)$$

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It has the property that more than 85 of the specimens in the diagram analogous to Fig. 1 lie to the left of it. The remaining specimens, which were to the right of the curve, contained: a) magnetic detritus of allothigenic origin and clasts with magnetic effects, b) more strongly magnetic rocks as a result of the filling in of cavities left by roots of recent vegetation, or of the underground activity of animals, c) an increased content of carbonates of post-depositional calcification, especially in eolites. The correlation diagram (Fig. 1) of the magnetic mass susceptibility $\varkappa$ and the carbonate content A is, to a considerable extent, a supplementary image to the relation between $\varkappa$ and the content of the clastic component. The clasts and carbonates in the specimens with a small content of organic matter form, to a certain extent, a complementary system. However, the ($\varkappa$, A) and ($\varkappa$, clasts) correlation diagrams differ substantially if the carbonate content $A < 6\%$. This is an interval in which the chemical properties of the carbonates have a smaller effect.

The granulometric investigations of the clastic component of the rocks has shown that $\varkappa$ depends, to a large extent, on the total surface area of the clasts and correlates fairly well with the surface area of silicate clasts and their gels. Microscopic analysis has proved that the magnetic minerals are mostly bound to the surface of the silicate particles and especially to the gels which surround them. It was also found that the mean size of the magnetite particles decreases and the content of hydrated ferromagnetic minerals increases very rapidly as the carbonate content in the rock increases above 40%. The upper limit of the content of ferromagnetic minerals when the surface of the silicate clasts and their gels is saturated by these substances can be identified with the boundary exponential (1). This is also supported by the fact that Eq. (1) holds in rocks abundant in organic substances. To determine the ratio of the ferro- and paramagnetic phases, it was assumed that the investigated rocks practically contain only magnetite in their magnetic product and that both phases can be reduced to a single ferrimagnetic mineral (haematite).

Fig. 2 shows the ($\varkappa$, D) correlation diagram in which the parameter D at first increases rapidly with decreasing $\varkappa$ (the percentage of the paramagnetic phase increases), reaches its maximum at $\varkappa = 5\times10^{-8}$ SI, and this, with a view to Fig. 1, corresponds to the upper limit of the carbonate content of 40%. The subsequent rapid decrease of D can be attributed to the displacement effect of the carbonates on iron compounds (Okac, 1961). In the region of the displacement effect, it is necessary to reckon with the content of the ferro- and paramagnetic phases changing, as well as with their qualitative changes in the course of the existence of the sedimentary rock. We found that the interval in which D increases with decreasing $\varkappa$ is closely related to the changes in the ratio of the ferro- and paramagnetic phases with the palaeotemperature at the time of sedimentation. This phenomenon is observed in magnetic products of authigenic origin in which the magnetic mineral is magnetite, and its origin is synchronous with sedimentation period of the rock.

In the interval of carbonate content up to 40%, the displacement of the highly dispersive paramagnetic phase is blocked to a large extent by the consevation effect of the surface of the silicate clasts and gels which envelope the ferromagnetic phase. The gels are considerably enriched by the absorbed paramagnetic minerals. The conservation effects of the silicates and their gels prevent larger changes of the ferro- and paramagnetic phases, especially during post-depositional recalcifications.

Quite different conditions apply during drift and sedimentary sorting when the ferromagnetic and paramagnetic minerals are deprived mechanically of the protective effects

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especially of the silicate gels. If carbonates are present in the resedimented rock, magnetite usually changes to Fe colloids. After the colloidal silicate and gel component has been renewed, these adsorb and coagulate on them, and this is associated with changes in the redox potential and pH factor. Provided the coagulates are sufficiently large, the coagulated colloids of the paramagnetic Fe minerals recrystallize into magnetic minerals. The paramagnetic coagulates are mostly immobile and, under spontaneous recrystallization, they are able to associate only to a limited extent. Many do not achieve the size necessary for the ferromagnetic state to originate.

The microscopic analysis of the studied set of samples proved that the spontaneous recrystallization of the paramagnetic minerals into ferromagnetic minerals was closely linked to crystallization nuclei, mostly silicate. They have the character of silicites which are formed from colloidal SiO_2 and are a manifestation of the initial stage of diagenesis (Petránek, 1963). The relict of chemical etching of magnetite particles (more than 300 experiments were made) was in each case a silicate particle. Larger magnetite particles had a larger number of silicate crystallization nuclei. The etching proved that these magnetite particles were in fact conglomerates of smaller particles cemented by the silicate gel. This is evidence that the conglomerates were generate by the conglomeration of independently crystallized magnetite particles.

The results reported above were derived from experiments we carried out, many of which went on without interruption for as many as 12 years. This concerns particularly the processes of disintegration of magnetite into colloidal phase due to the effect of carbonated, the processes of coagulation under various redox and pH conditions, the processes of spontaneous recrystallization of paramagnetic minerals, the renewal of silicites in the rock and the temperature dependence of parameter D . These experiments can be used to estimate the time required for the new ferromagnetic phase to be generated in dependence on temperature. The estimated time is between 50 and 200 years, reduced to natural conditions.

One of the factors which support the predominantly authigenic origin of the magnetic product in the Quaternary sedimentary rocks being investigated is the dependence of the magnetic mass susceptibility $\varkappa$ on the temperature at the time the rocks settled. We observed this relation along several geological profiles in whose rocks the silicate clasts have been sorted, and that there exist specimens with nearly the same weight ratio of clasts - carbonate - iron. The locality of Dolni Chabry, which has these properties, displays a high degree of correlation of the magnetic mass susceptibility $\varkappa$ with the in--phase values of the curve of changes of concentration of isotope ^{18}O in the planktonic foraminifera of marine sediments (Fig. 3). It is known that the ratio $^{16}O/^{18}O$ is a function of the temperature at the time of the sedimentation of the plankton (John, 1979). Fig. 3 shows the values of the magnetic mass susceptibility $\varkappa$, the concentration of isotope ^{18}O, the total content of Fe in the rock and parameter D for the interval of 0 to 8.3×10^4 yrs B.C. The percentage of the ferromagnetic phase and, consequently, also the value of $\varkappa$ decrease with the palaeotemperature at the time of the origination of the authigenic magnetic minerals. On the contrary, the percentage of the paramagnetic component, represented by the parameter D , increases.

Let us assume that the intensity of the geomagnetic field did not change over a longer period of sedimentation (H = const.). The value of the Königsberger factor Q for the samples of the sedimentation period being considered will also be constant, provided the stable component of the magnetic polarization is assigned an adequate part of the value of the magnetic mass susceptibility $\varkappa$. As already mentioned above, the magnetic mass

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susceptibility of the whole product dpends on the paleotemperature at the time of sedimentation. If we substitute the value of $\varkappa$ into Q at H = const., we subject the Q-factor to this temperature dependence. In studying the magnetic properties of ferrites, obtained chemically and by crystallization on the surface of the pores of ceramic frits at H = const, but under various temperatures we found that the stable component of the magnetic polarization has to be assigned a value of $\varkappa$ proportional to the factor $D^{-1/2}$. For H = const., also Q was then constant within a certain interval of D . One may assume that an analogous relation for compensating the effect of the palaeotemperature will also hold for sedimentary rocks. In this case, one must bear in mind particularly that a) the magnetic product must be of authigenic origin, b) the palaeotemperature and the period in which the magnetic product originated must be in phase, c) the displacement effect of carbonates must have no influence and, therefore, specimens with $5x10^{-8}$ SI must be excluded, and d) the physical and chemical properties of the specimens must be sufficiently homogeneous.

The method of compensating the dependence of the magnetic mass susceptibility of rocks on the palaeotemperature at the time the magnetic product originated by means of the parameter D was used to determine the value of the Q-factor. Localities of eolites and nival sedimentary rocks whose sedimentation could be quaranteed to be in phase to a sufficient extent were selected for this purpose. The values of the Q-factor for localities spaced at about 300 km where the sedimentation took place under different conditions were nearly the same at the in-phase points of the time scale. These values of the Q-factor were also correlated with the synchronous values of the total geomagnetic intensity F/F_0, determined by the method of double consecutive heatings of archaeological samples (Bucha, 1975). For (Q, F/F_0) the correlation coefficient $r = 0.92$. If the susceptibility was not compensated for the palaeotemperature, $r = 0.32$.

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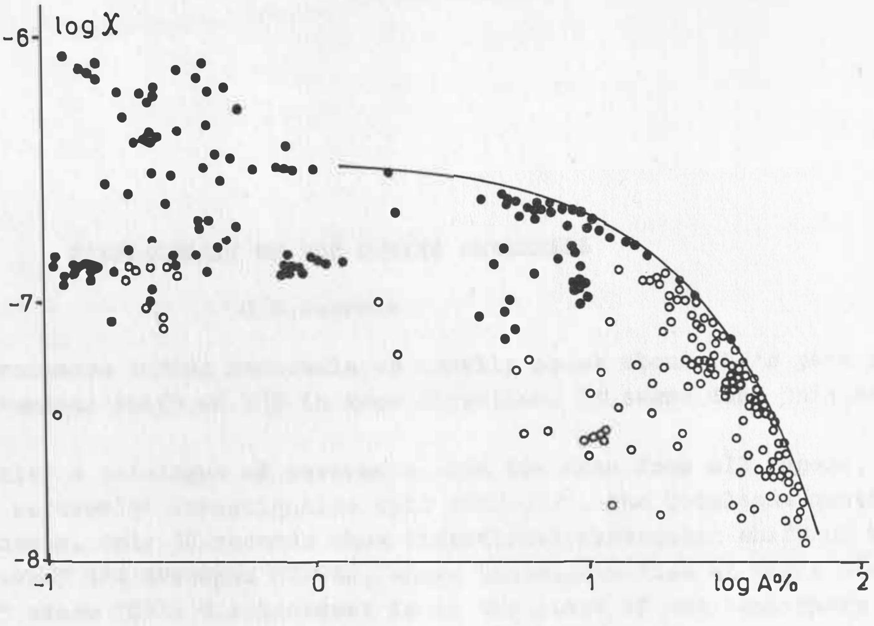

Fig. 1. Correlation diagram of magnetic mass susceptibility [SI] and carbonate content A [%].

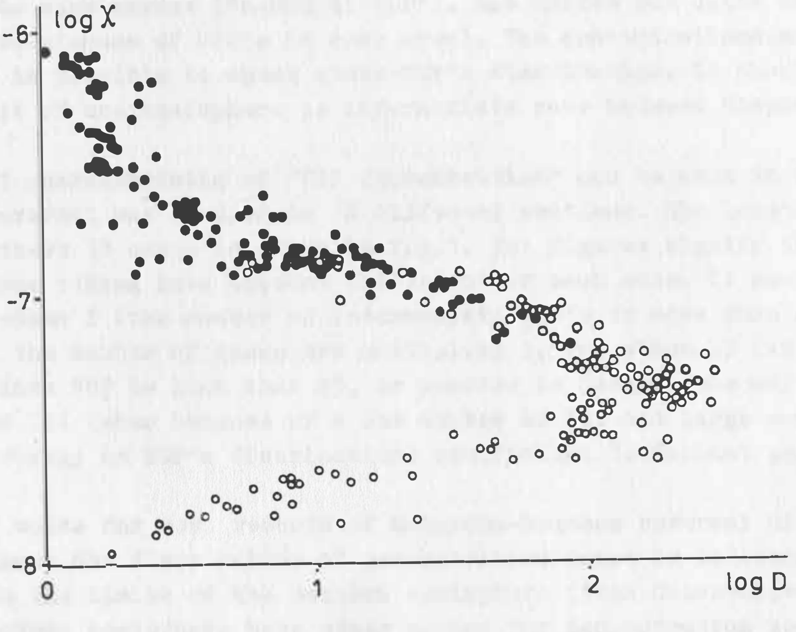

Fig. 2. Correlation diagram of magnetic mass susceptibility [SI] and ratio D of magnetic phases.

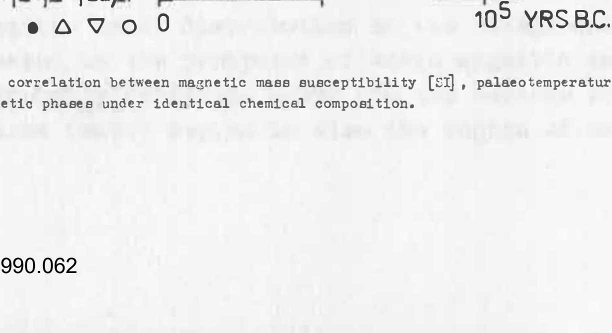

Fig. 3. Time correlation between magnetic mass susceptibility [SI], palaeotemperature and magnetic phases under identical chemical composition.

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DISPLACEMENT OF VGP DURING REVERSALS

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Discussing processes during reversals we usually speak about VGP's path or trajectory, meaning systematic shift of VGP in some direction. It seems that this characteristic is not real.

We have compiled a catalogue of reversals with the data from all papers, published from beginning of reversals' investigation till 1983 /1/. The Catalogue contains 126 cards, 95 for Cainzoic. Only 12 records show directional systematic shift of VGP. From these 12 cases 3 cases are averaged curves, where inhomogeneities of VGP's distribution are smoothed. In 5 cases VGP's displacement is in the limit of one hemisphere only. There are only 4 cases of real eystematic meridional VGP's displacements.

The real picture of VGP's distribution is concentration of VGP in some region. The concentration can be very narrow ("swarm of VGP"), not narrow but quite distinct or diffused one (only predominance of VGP's in some area). The concentrations make 70 per cent of all cases, when it is possible to speak about VGP's distribution. It should be said that VGP's shift in limit of one hemisphere is intermediate case between displacement and concentration.

The reality of characteristic of "VGP concentration" can be seen in fig.1 and 3. Matuyama-Brunhes reversal was studied in 18 different sections. The location of concentration zones for these 18 cases is shown in fig.1. The figures signify the number of hits in the same zone taking into account the weight of each case. It means that for reversal records of class I (the number of intermediate VGP's is more than 25 and the scatter is not large), the number of cases are multiplied 3. For class II (it is either the number of intermediate VGP is less than 25, or scatter is large), the multiply coefficient is 2. For class III (when because of a few number of VGP and large scatter it is not possible to speak surely on VGP's distribution) coefficient 1. Maximal possible number of hits ie Pmax.

Concentration zones for most records of Matuyama-Brunhes reversal hit in the same region. As fig.2 shows the distribution of concentration zones is independent on longitude of sampling in the limits of the eastern hemisphere (from Chechoslovakia till Japan), but sections in western hemisphere have other region for concentration zones.

It means: firstly, concentration zone is useful characteristic of a reversal processes; secondly, geomagnetic field during Matuyama-Brunhes reversal was not dipole one, but its nondipole terms have space scale as large as world magnetic anomalies.

In fig.3 all VGP's outside of concentration zones for all records of Matuyama-Brunhes reversal are shown including VGP of records with no distinct distribution of VGP. The absence of any regularity confirms possibility to use only concentration zones as a characteristic of the processes during reversals.

The locations of concentration zones for reversal of different ages are not the same. For reversal older than Gauss-Matuyama distribution of concentration zones begins to be less distinct. It is understood because, firstly, each picture includes several reversals of not the same but near age and, secondly, the datings in many cases are not sure and sometimes doubtful.

Fig.5 shows the concentration zones distribution on the background of world magnetic anomalies. Most zones are located on the periphery of world magnetic anomalies, mainly their east slopes (sides). Generally speaking, there are two regions of concentration zones nearly opposite. The first (east) region is also the region of magnetic centres

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projection for the whole Cenazoic and maximal equatorial Earth's radius lays also in this region.

For explanation of this distribution such a hypothesis can be proposed. World magnetic anomalies are the reflection of coremantle boundary inhomogeneities. Near these inhomogeneities small-scale turbulence takes place. During stationary field the secular variations are connected with this small-scale turbulence. Before a reversal magnetic moment of Earth decreases approximately trice. There is no supposition about the case of this decrease but such variation of magnetic moment is known even from archaeomagnetic data. Small-scale turbulence is suppreesed by geomagnetic field. When magnetic field decreases, small-scale turbulence develops and drives down main convective motions.

Convective motions begin to occupy less part of liquid core comparing to stationary regims that is why magnetic moment decreases further. Small-scale turbulence is more energetic process in comparison with main convection, it goes down in the course of time. This scheme corresponds to experimental picture: decreasing geomagnetic field, on its background increasing variation, further decreasing of intensity and then the displacement of VGP in low latitudes. Dipole field does not vanish completely: in some cases we can see variation of intensity about 10th years, which is considered as eigene oscillation of dynamo-mechanism.

According to this scheme VGP during reversals is to be connected (one way or another) with world anomalies. Thus, the existence of concentration zones is more possible than any trajectory of VGP /2/ .

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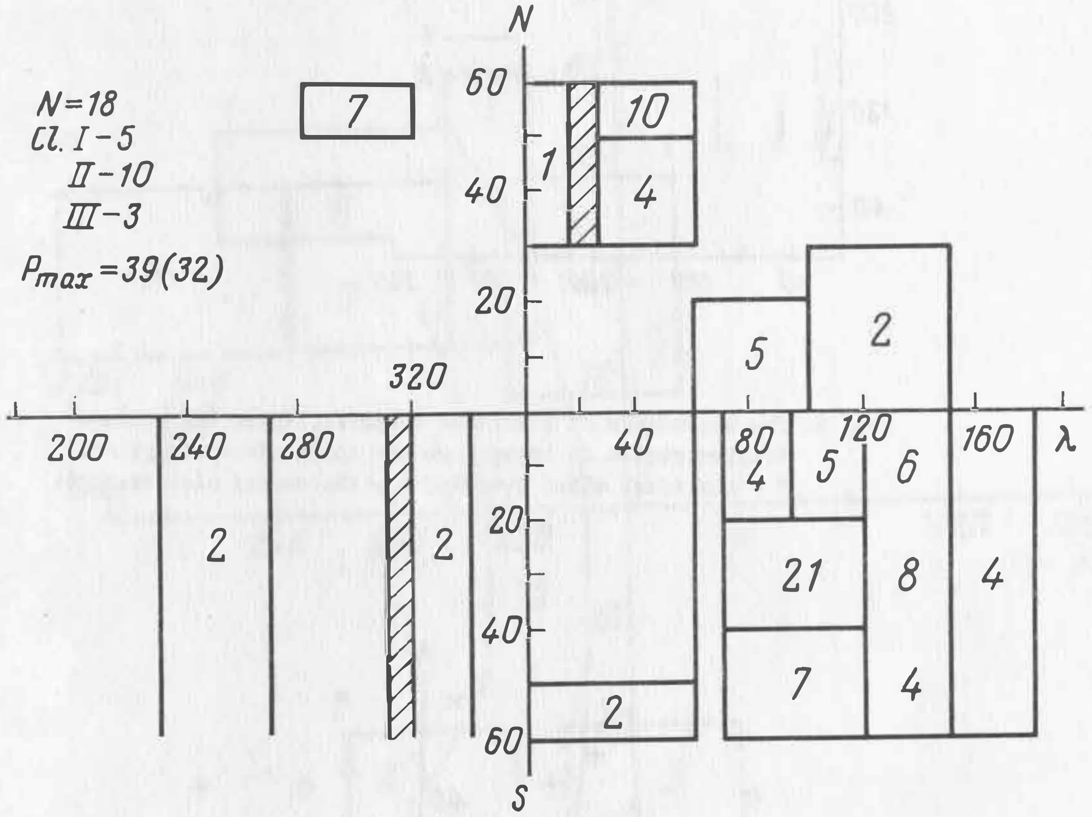

Fig. 1. Distribution of VGP concentration regions for the Matuyama-Brunhes reversal. The figures mean the number of hits of VGP concentration regions on the very coordinates. N - the number of cases (records of Matuyama-Brunhes reversal on different coordinates); P_{max} - a maximal p possible hit. Class I,II,III - characterizes, how distinct the VGP concentration region is seen on the record.

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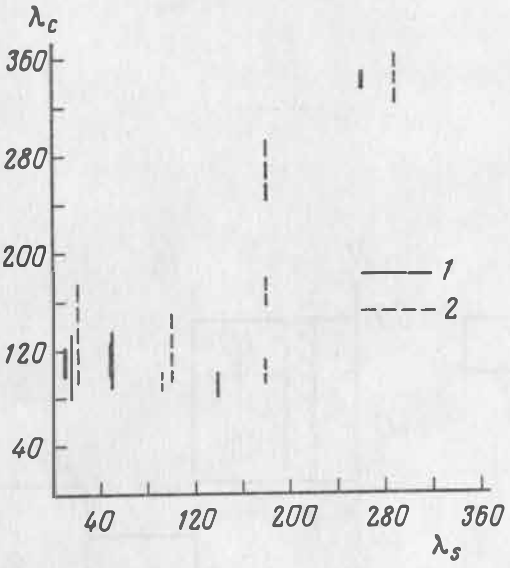

Fig. 2. The dependence of longitude interval, where VGP concentration region is located on the longitude of sampling. 1 - the first class records, 2 - the second class records.

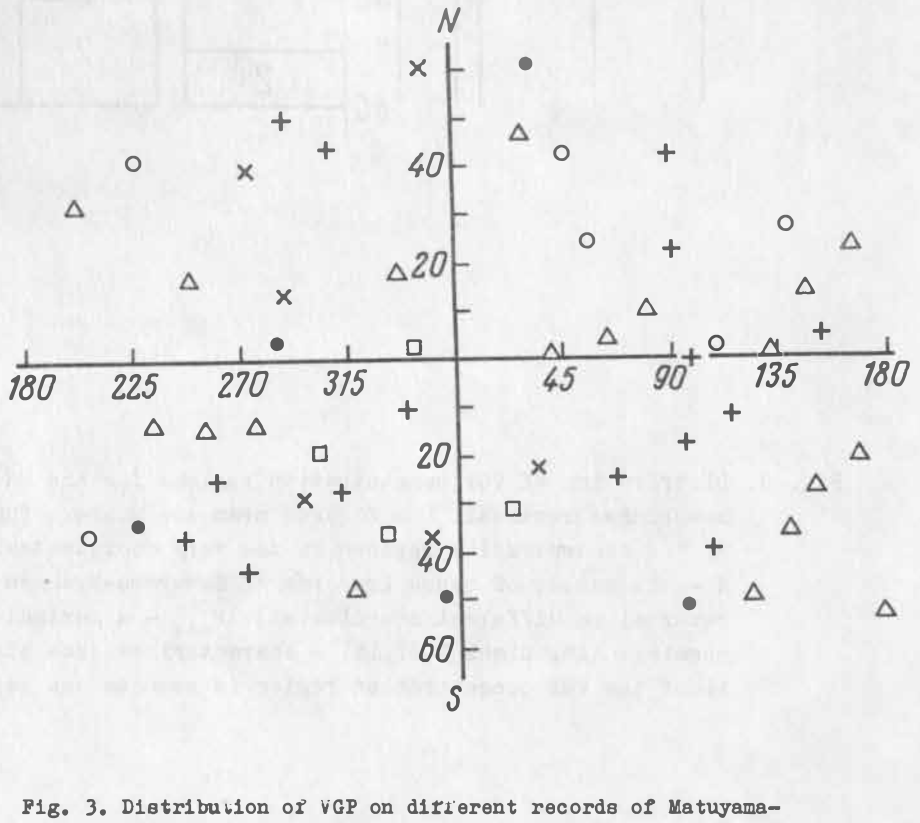

Fig. 3. Distribution of VGP on different records of Matuyama-Brunhes reversal. These VGP do not belong to the VGP concentrations regions. Different points refer to different records of Matuyama-Brunhes reversal.

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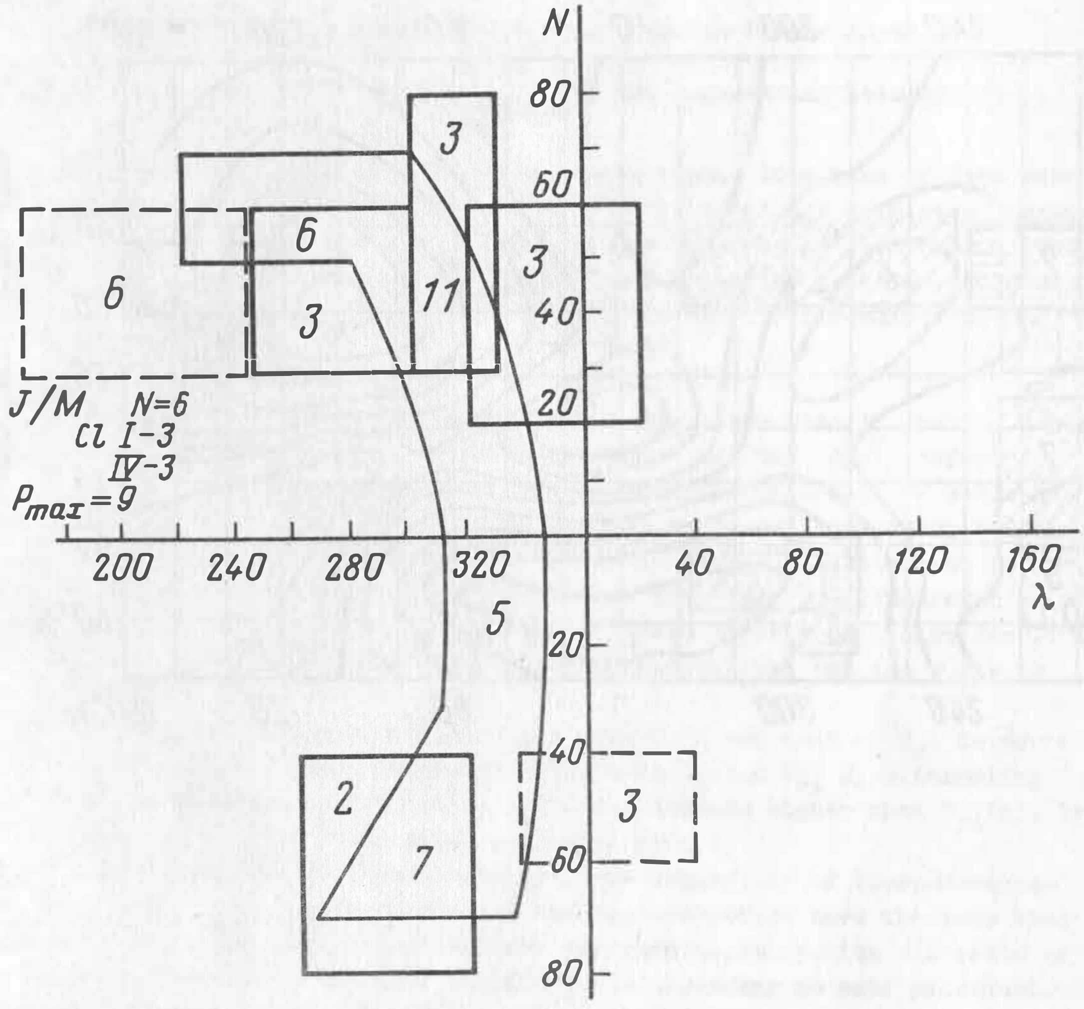

Fig. 4. The VGP concentration regions for reversals Jaramillo-Matuyama (dotted lines) and Matuyama-Jaramillo (full lines).

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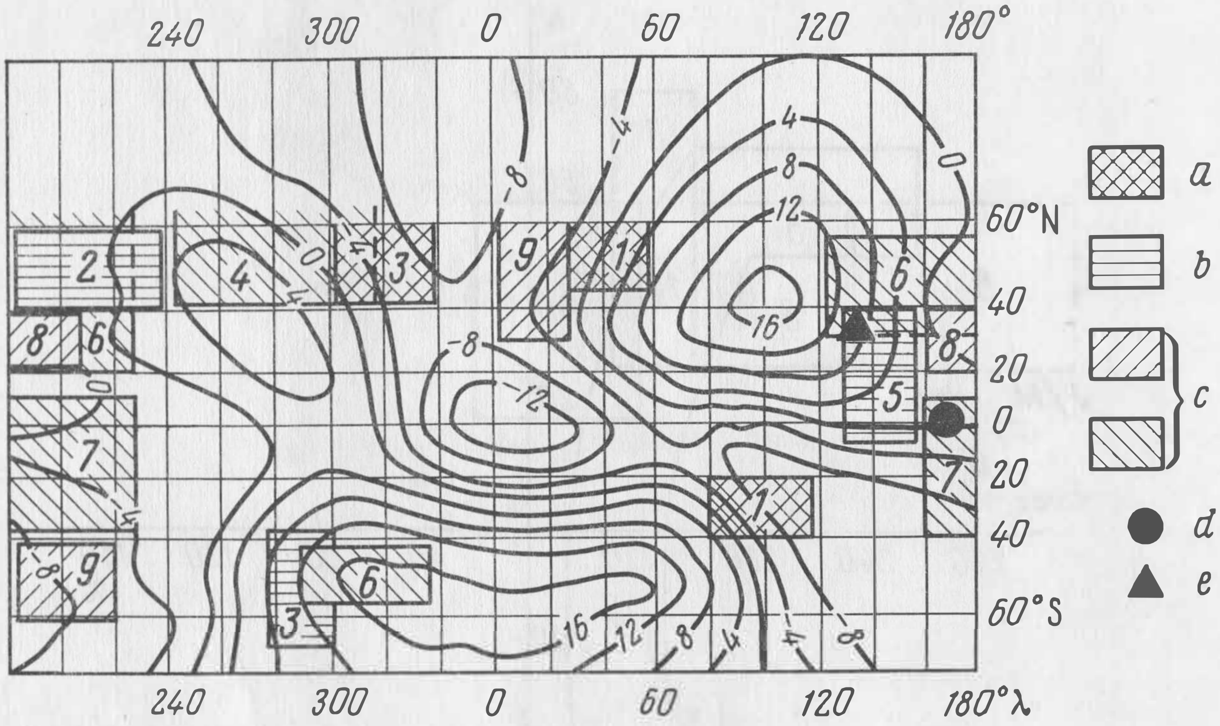

Fig. 5. The place of VGP concentration regions, being typical for reversals of different age, regarding to modern nonuipole field.

a - coincident data from different regions
b - different sections of the same region
c - isolated data for different reversals
d - maximal equatorial radius of the Earth
e - projection of magnetic centre for Brunhes epoch.

Reversals:

1 - Matuyama-Brunhes,	2 - Jaramillo-Matuyama
3 - Matuyama-Jaramillo	4 - Between Gauss Matuyama and Matuyama-Jaramillo
5 - Gauss-Matuyama	6 - Younger than 4 mln years
7 - 5-8 mln years	8 - 13-15 mln years
9 - 30-50 mln years	

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ESTIMATION OF NRM ORIGIN IN QUATERNARY SEDIMENTS

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Correct estimation of NRM origin is of especially importance in a case of fine structure of geomagnetic field study. At the same time many statistical and consistent tests used in paleomagnetism for primary magnetization revealing begin to be less useful by fine structure investigation. The test which is considered to be the best for sediments - laboratory resedimentation - is not always possible and sometimes its results are uncertain.

We use some other tests.

1. If value of anhysteretic magnetization in 3-6 times greater than I_n, but I_n demagnetization curve in alternate field $I_n(h)$ is located higher than that of I_{ri} after I_{rv} excluding, I_n most probably is DRM. More distinct results can be obtained for sediments with only one ferromagnetic. This test is quick and suitable for all sediments, but it should be kept in mind that comparison of natural and unhysteretic magnetization is not accurate because of ignorance of ancient field intensity. This test is illustrated in fig.1. The demagnetization curves of I_n and I_{ri} were obtained by averaging data for 20 samples. Natural magnetization is 5 times less than anhysteretic one but its curve is deposed lower.

Zijdervield temperature diagrams show that I_{rv} is about 50 per cent of I_n. It means that the curves must be compared after demagnetization both I_n and I_{ri} by alternating field of 15 mT . After such a demagnetization $I_n(h)$ is disposed higher than $I_{ri}(h)$. It can be considered as an indication on detrital nature of NRM.

2. If a rock contains two or more ferromagnetics, the comparison of thermodemagnetization curves of I_{rs} and I_n shows whether these two ferromagnetics have the same kind of magnetization or not. If two ferromagnetics have the same magnetization the ratio of their contributions in I_n would be the same as in I_{rs}. If according to some peculiarities of ferromagnetic grains (composition, shape, location, distribution) one of these ferromagnetics can be considered as a carrier of definite magnetization - the detrital one, for example - such comparison allows to judge about magnetization of another ferromagnetic.

In fig.2 a thermocurve of I_{rs} is given. The figurative points represent I_n for different samples. Point 1 is for the samples which obtain magnetite and titanomagnetite. Direction of magnetization does not change after T_c of titanomagnetite. The grains' shape both for magnetite and titanomagnetite evidences about their detrital origin. As can be seen, figurative points I coincide with the I_{rs}-curve. Figurative points 2 for a sample with both titanomagnetite and magnetite, but magnetite is the secondary one and does not carry any remanent magnetization. Figurative points 3 for a sample, which has two stable magnetization with different directions. This sediment contains magnetite and titanomagnetite as well. Magnetite grains are very fine, their distribution is inhomogeneous. Direction of I_n component connected with magnetite changes from a sample to the neighbouring one more sharp that titanomagnetite component. We consider the magnetite magnetization as CRM.

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3. In a section where sediments contain magnetite and titanomagnetite and their relative contain varies significantly along the section, the absence of correlation between ratio of magnetite and titanomagnetite components and I_n value is an argument in the favour of detrital origin of NRM. The reason of it is that titanomagnetite carries only DRM and if magnetite has CRM, NRM of samples with predominance of magnetite must be greater.

Fig.3 shows the dependence of I_n from the ratio of titanomagnetite and magnetite components. The ratios were estimated upon the amplitudes of titanomagnetite and magnetite maxima on the curve of thermodifferential analysis. As can be seen, by change of relative concentration of magnetite and titanomagnetite from 1,2 to 18,0. I_n varies in narrow limits. Less values correspond to magnetite, it would be impossible in case of chemical magnetization of magnetite. The detrital nature of NRM for these sediments was checked up by resedimentation.

4. In a section where large variations of H_{cr} are noticed the dependence of I_n value from H_c can be used for estimation of NRM nature. In a case of CRM I_n value increase with H_{cr} increasing (that is with grain size deminishing). I_n of detrital magnetization reaches its maximum by middle grain size. Both by decreasing and increasing of H_{cr} I_n decreases. It is easy to understand such dependences from general consideration, but nevertheless they were discussed theoretically and checked up experimentally by Dunlop, Scherbakov, Bagin, Pechersky, Nguen and others [4, 5, 6, 8, 9].

Fig.4 shows the dependence of I_n from H_{cs} for investigated sediments. In order to exclude the concentration effect not I_n, but I_n/I_{ri} are plotted on ordinate axis.

H_{cr} about 100 mT for titanomagnetites or magnetites evidences the presence of fine grains approaching single domain region. The great decreasing of I_n for these grains contradict the supposition about CRM but is in agreement with the DRM characteristics. DRM must obtain its maximum when the grains are small but far from single domain ones, $H_{cr} \sim$ 40-50 mT characterizes the grains of this diapazone. The grains about 0,01 are seen with the help of microscope.

Chemical magnetization characteristics are not yet studied enough but last years two groups of researchers of Institute of Physics of the Earth have investigated them: Pechersky and Nguen for magnetite [4, 8, 9] and Bagin, Gendler, Avilova for haematite [5]. Chemical magnetization appears to be in all cases similar to anhysteretic one. For magnetite ratio of chemical magnetization to anhysteretic one can vary from 0,5 to 1,5. It depends on the origin of magnetite: if magnetite is a product of some paramagnetic distruction (crystallization magnetization) its magnetization would be a few greater than I_{ri}; if magnetite is a product of primary ferromagnetic grain change its magnetization would be a few less than I_{ri}. Demagnetization curves practically coincide.

For soft haematite chemical and anhysteretic magnetization have similar demagnetization curves, but chemical magnetization can be twice less. It is impossible technically to obtain the full anhysteretic magnetization in the case of hard haematite. The dependence of chemical magnetization value on grain size and correspondingly from H_{cr} is distinct just for hard haematite.

In order to be sure we always try to use a collection two or more tests mentioned above.

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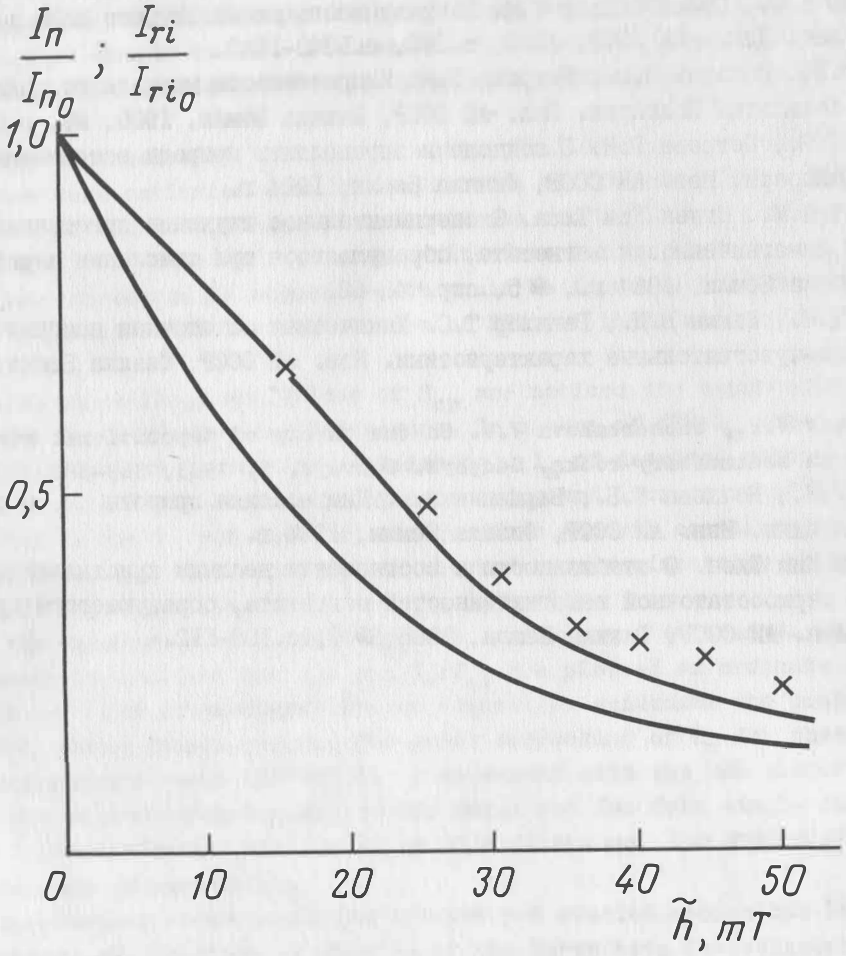

Fig. 1. Comparison of I_n and I_{ri} values and their demagnetization curves in alternate field

1 - Iri(h) curve, averaged upon 20 samples,

2 - I_n(h) curve, averaged upon 20 samples,

3 - I_n values, recalculated after I_{rv} excluding.

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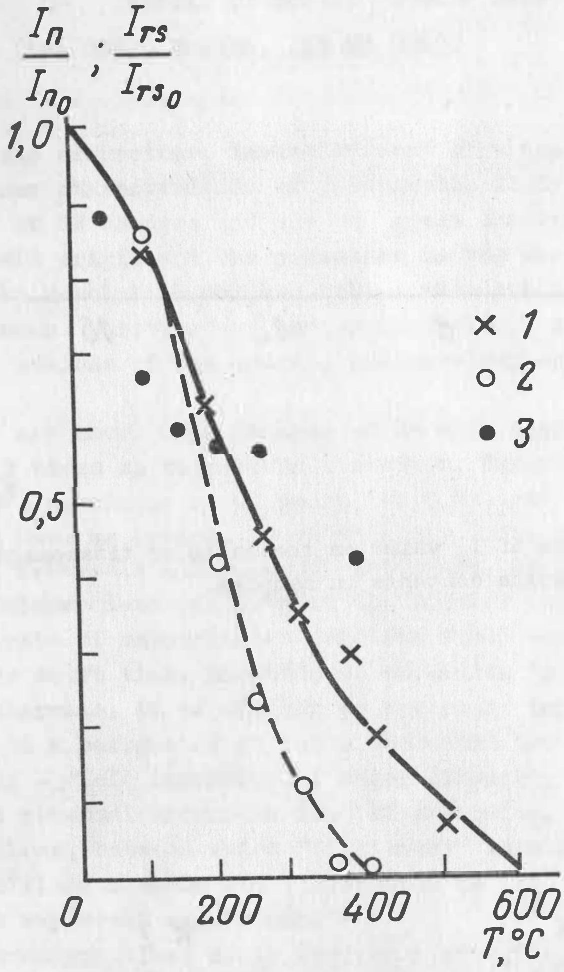

Fig. 2. Comparison of $I_n(t^o)$ with $I_{rs}(t^o)$. A firm line - I_{rs}; figurative points - I_n of different samples, described in the text.

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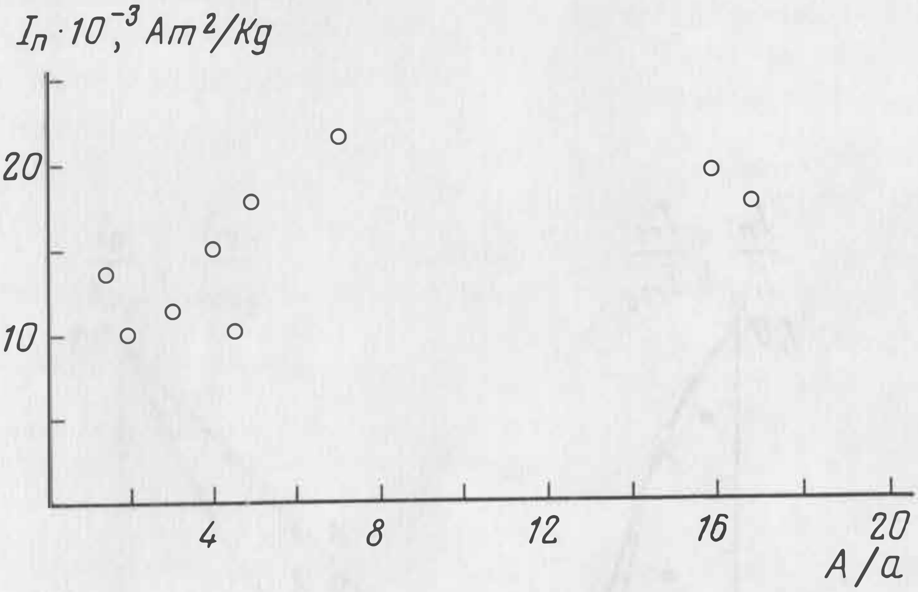

Fig. 3. Dependence of I_n value on the ratio of titanomagnetite and magnetite contents in samples.

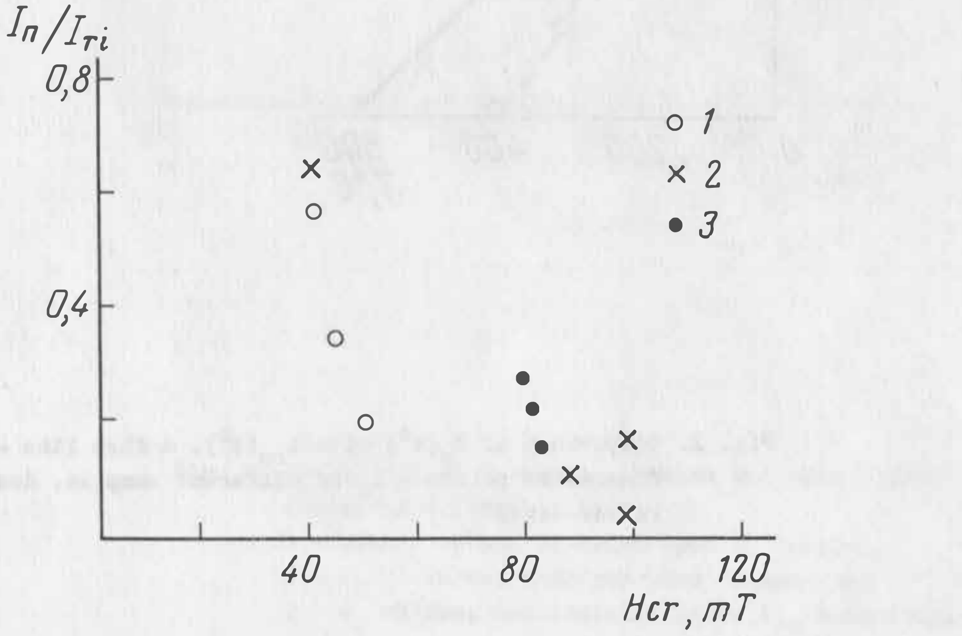

Fig. 4. Dependence of I_n value divided by I_{ri} for concentration excluding on the grain size expressed by H_{cr}.

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EXCURSIONS OF THE BRUNHES CHRON AS THE BASE OF MAGNETOCHRONOSTRATIGRAPHICAL SCALE FOR THE QUATERNARY
(REVIEW OF SOVIET AUTHORS DATA)

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Introduction

Geomagnetic field excursions, investigations of which began 10 - 15 years ago, can be considered as a new characteristic of geomagnetic field (GF) changes. Excursions enlarge our knowledge of GF changes and are of great importance for understanding the Earth's magnetic field origin and the processes in the Earth's core. The excursions, as time marks with great resolution ability have a wide application in the other branches of the Earth's sciences: stratigraphy and geochronology, sedimentation processes and tectonics (vertical motions of the crust), paleontology and climatology and, even in archaeology.

The excursions are short-time changes of GF with high amplitudes exceeding normal deviation level by 3 times up to reverse direction. Excursion duration is very limited: of an order of $n.10^3$, sometimes $n.10^2$ years (that is less than the main dynamo period - 10^4 y). Excursions have as common, so essentially different features comparing with secular variations, reversals and polarity intervals. Amplitude of GF direction change for excursions is intermediate one between the secular variation and polarity interval amplitudes. In the case of excursions a complete field reversal is observed often enough, but it occupies very short time. Duration of excursion is significantly shorter than that of polarity intervals, it is similar to reversals duration. Unlike reversal process, excursion develops on a background of not a decreased but varying - sometimes increasing, sometimes decreasing - field intensity. A sharp intensity decrease is obtained sometimes if a complete field reversal occurs in time of excursion. Excursion could be described as a number of impulses, between which "stationary" secular variations are seen.

The geomagnetic field changes are illustrated in fig. 1, where straight lines with circles at the ends represent excursions.

Magnetochronostratigraphical scale for the last 4,5 mln y does not contain geomagnetic excursions (Cox, 1969) . The geomagnetic chron Brunhes represents polarity interval in which GF is similar to the present day one. Not so long ago discovering of an excursion in paleomagnetic section has been considered as uncommon occurence. Numerous investigations that have been carried on during the last years, showed that as in the Brunhes chron , so in chrons of the another polarity the geomagnetic excursions are presented. Excursions are revealed in different sites of the globe as on the continents, so on the oceans. Excursions are found within different geological times: Palaeozoic, Mesozoic, Cainozoic.

The main information is for the Quaternary period, what can be easily explained: the younger rocks are less altered, excursion records are not wiped off by superposition of the secondary magnetizations.

I. Investigation of geomagnetic field excursions

In the end of sixties detailed paleomagnetic studies, together with biostratigraphical works, were carried out with the Pleistocene-Quaternary continental sediments southward of the western Siberia (Pospelova, 1971) and in some sections in Czechoslovakia (Bucha, 1976). It was shown, that in sections which could be refered to

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Matuyama and Brunhes times, besides intervals of direct and reversed polarity, transitional zone and secular variations, some new GF oscillations were recorded - excursions. Within sections of great thickness were revealed 7 - 10 layers having anomalous direction of the primary magnetization.

Usually, under classical paleomagnetic investigations the sharp deviations of direction in some samples out of a great number examined, is ascribed to a random errors and such data are either rejected or averaged with the adjacent ones. At first a suggestion was offered, that anomalous direction of magnetization are due to experimental errors. Special drilling carried out close to the outcrop and additional sampling showed that this suggestion was groundless.

It was confirmed, that the anomalous direction of the primary magnetization was observed at the same depths; the magnetization peculiarities being seen more clearly when cores from the bore were used (fig. 2). Some layers having the anomalous magnetization directions were traced over a large distances. Field and laboratory examinations indicated to the fact that such anomalous magnetization could be explained only by the GF behaviour during the rock formation, though the excursion existence itself appeared to be impossible: from the view point of hydrodynamo theory changes of the field directions up to the opposite ones during such a short time span could not be explained. At present, there is an attempt to bind up the GF excursion with phenomenon on "the oceans" - stratiphisized layer of decreased density at the core-mantle boundary (Braginsky, 1984) .

The study of excursions is a matter of a great difficulty first of all due to their shortness. Besides, not all the anomalous directions, found in sections, are of geomagnetic nature. False excursion can arise due to sedimentation under turbulent flows, particle accumulation on a steep-declined plane, in result of post-sedimentation deformations. In bores, especially in bottom ones, false excursions can occur in result of crampling and deformation of rocks in a core. Change in composition and structure of magnetic minerals during their life-time may lead to formation of anomalous magnetization direction. So processes going to freeze ground within cryolithogenesis zone can change direction of the primary magnetization and its value (Minyuk,1986). Pseudoexcursions occur under deformation in sediments with drainage lines (Bakhmutov, 1986) , as well as in a result of soil-formation of certain loess-soil complexes (Faustov, Virina, 1986) . On the other hand the true excursion records may be partly or as a whole concealed on account of magnetic viscosity, chemical changes during rock erosion, repeated wetting and so on. Therefore it is not surprising that sections containing excursion records are revealed more seldom, than sections without excursions. Naturally a great attention is paid to clearing out the pseudoexcursions and to proof of the data reliability. Excursion examination requires special methods as during sampling, so when laboratory experiments are carried out. The true excursions are to be confirmed by the inner agreement between the data for each outcrops (it should be traced through some excavations) and there should be time-spatial fitting of data throughout the whole region.

Three methods can be used for geomagnetic excursion investigations:

I. To estimate a number of excursions during a certain time-interval the most complete and long sections, enveloping a great time-interval, are taken - for example, a part of Matuyama chrone and the whole Brunhes chrone. Detailed continuous sampling of sec-

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tions with thickness more than 100 m, allowed to discover a series of excursions (Pospelova, 1971; Bucha, Sibrava, 1977; Creer, 1980; Pospelova, 1981; Tretyak, 1983). (see fig. 3). A deficiency of this method is a possibility, that by examination of a single section, in the case of bottom sediments especially, some pseudoexcursions, that are not connected with the geomagnetic field changes can be taken as true ones.

The second method, that is popular in the USSR, allows to define true excursions within the given region. This method consists in a choice of sections being stratigraphically of the same age and enveloping a limited time-interval, so that they can be correlated rather surely over a great area. The excursions, revealed in these sections can be surely correlated too and then assumed to be certain stratigraphical marks within large areas. Using this method the regional magnetochronostratigraphical scales were compiled of the Quaternary time for the Caspian and the Black Sea basins Eremin, 1986; Zubakov, Pisarevskii, 1982; et al.) for Moldavia and the Ukraine (Tretyak, 1983; Adamenko, Pospelova et al., 1982) for south of the Western Siberia (Pospelova et al., 1982) , for the GDR and Bulgaria (Wiegank, 1979, present monography) ; in the other countries this method was not utilized.

The third method - paleomagnetic investigation of rocks within separate outcrops, which are dated geochronometrically at not less than two points. Such investigation allows to define accurately enough the excursion age and duration (Nachasova, Burakov, 1984; Maisuradze et al., 1986; Dudkin, 1986; Pospelova, 1986).

The third method is widely used in a number of countries; the investigations carried out on Japan tuffs of 30 thousand years dating by C^{14} are of great interest (Tanaka, Tachibana, 1981) , on basaltic flows in Idaho, USA, their age estimated as 450 ± 50 thousand years with the K-Ar method (Champion et al., 1981) and a number of the others. To compile the magnetochronostratigraphical scale investigations, based on the third method, are quite necessary ones.

Each of methods, described above, possesses its own advantages and defects, but their joint application appeared to be successful for compilation of magnetochronostratigraphical scale of the Pliocene-Quaternary time.

For the excursion investigation interpretation of linear magnetic sea-anomalies is of great importance. The design of the linear magnetic anomalies, when compared with the Brunhes chrone, showed evidently enough an existence of excursions within this chrone. An improved analysis method, that has been developed during last years, allowed to outline within the Brunhes chrone the Blake excursion. This excursion is confirmed by reversly magnetized samples, collected in the Middle Atlantic valley in the zone of this anomaly and Emperio excursion, its age ~ 490 ± 50 thousand years and duration similar to that of the Blake excursion (Wilson, Hey, 1981).

2. Excursions of the Brunhes chron , based on the Soviet investigations

Up to the present in the USSR a great number of experimental data is obtained on geomagnetic field excursion during the Pliocene-Quaternary time. As investigation objects sedimentary rocks of different genesis were used: continental, sea, bottom lake sediments, sea and ocean floor and even cave sediments, more seldom volcanic rocks. Excursions are revealed in rocks from outcrops and bore-specimens. New data have emerged excursions, that could be marked out in archaeological objects. The greater part of data on the Brunhes chron excursions, which is based on the Soviet investigations, is

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systematized in tables I - I3. For some large regions, where a number of independent studies have been carried out, for the Brunhes zone summary paleomagnetic sections are compiled. Each table could be considered as a regional magnetostratigraphical scale. Some of these tables contain regional stratigraphical schemes. These schemes, as well as their correspondence with the Pleistocene subdivisions, should be considered as a rough and preliminary ones. Their will be improve in process of future investigations.

The data, presented in the tables are of different significance and reliability. Excursions found on territories of the Ukraine and the Western Siberia and especially within the Caspian Basin are traced in a great number of sections distributed over vast area, but as well there are excursions investigated in isolated sections only. For better understanding the tables are accompanied by a scales of outcrops and excavations, where these excursions were recorded. The results, obtained for excursions revealed in rocks from the Eastern Siberia, the Far East, the Okhotsk Sea are rather scanty and therefore combined into one table. Due to the same reason one table is given for the results from the north-european part of the USSR: the Priladojie, the White Sea, Lithuania. Excursions, revealed in morains are gathered in a separate table, because for such kind of sediments a method for estimation of the GF fine structure is not developed sufficiently well. Data lacking even rough age estimations and revealed in the region in a single section only, are not included in the tables. If age estimations are not sufficiently accurate, the limits of their possible changes are shown by a line, arrows correspond to displacement up and down the scale, which may be connected with age errors.

Excursion that are not based on several sections or excavations data are shown by dotted line, those not reliable ones by broken line.

In the USSR the better elaborated and widely known stratigraphical scheme of the Quaternary sedimentation is the scheme of the Black Sea - Caspian region, based on exploration of sea-fauna. Paleomagnetically the Black Sea - Caspian Basin is investigated fundamentally and over a vast area. Table I illustrates the scheme of Quaternary sediments of the Caspian Basin (The USSR Stratigraphy, Quaternary System, 1982, 1984) . This table contains the result of excursion investigations, carried out within the Caspian Basin, including data for the Russian Plain and bottom columns of the Caspian Sea. Within vast territory of the Caspian Basin different scientists have obtained excursion records in deposits of the upper and lower Khvalin, in different facieses of the upper and lower Khazar, deposits of which are spreading over many hundred kilometers (Eremin, 1986) . In this region time and spatial agreement between excursions is settled. Within the Middle and Late Pleistocene 5 excursions are marked out with certainty which can be correlated roughly with excursions revealed previously. Early Pleistocene Post Baku and Baku sediments are studied insufficiently. The first attempt of more detailed examinations of Baku deposits showed a presence of one excursions (table I).

Not less interesting are studies carried out within the Black Sea Basin (table 2). During the Brunhes chron there were settled nearly II excursions, 6 of them related to the Middle and 2 to the Early Pleistocene. It is possible that some of these excursions, located close in time represent one excursion with two jumps similar to the

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Upper Khazar excursion in the Pricaspian region. It should be noted, that in sea-sediments of the Black and the Caspian Seas are revealed some regular, sometimes rather long gaps, which occured during glacial-eustatic sea-regressions. Seven regressions were revealed in sea sediments of regions adjacent to the Black Sea; these regressions occured during the last 700 thousand years. Sedimentary rocks, corresponding to these time-intervals, are either absent or breaks in sedimentation sequence are filled up with continental sediments. As result a number of excursions, revealed in sea-sediments, can be incomplete.

During Quaternary time continental deposits predominate on land and it appears that just they provide more complete geomagnetic field record. Detailed areal investigations of the continental Quaternary sediment with the aim to detect excursions and to trace their inter-correlation, were carried out on the following territories: the Ukraine, Moldavia (table 3), in Zacarpathian region (table 4), in the Predurals (table 5), the Western Siberia (table 6) in the GDR and Bulgaria (the present monography) and the others.

Paleomagnetic data for the flat part of territories of the Ukraine and Moldavia are given in table 3. It appears, that table 3 is the most complete data collection for these regions. The table is based on A.N. Tretyak's results (Tretyak , 1976-1983) filled up with the other authors' data on Middle and Late Pleistocene, which confirmed his results. As stratigraphical scheme is adopted Veklich's scheme. In this scheme ortostage boundaries of loess formation are adjusted to "the absolute" age using a complex of methods (Veklich, 1985) . Chronology of the Dniestr terraces is given taking into account the results, given in (Chepalyga, Kulikov, 1985) and the data of IV All-Union Quaternary Conference (Guidebook, 1986) . This allowed to improve the age estimations of excursions within separate stratigraphical horizons and time scale. Excursions in the Middle and Late Pleistocene are revealed surely enough, while those, belonging to the Early Pleistocene are defined with some uncertainty.

There is an opinion, that subaerial complex of loess-soiled sediments of the Ukraine and the south of Moldavia cannot be used to study the geomagnetic field fine structure (Faustov, Virina, 1986) . In fact fossil soils are very complicate objects that require special methodical examinations. Strong viscous magnetization in soils conceals sometimes the primary magnetization and thus prevents to obtain the real ancient geomagnetic field pattern. However, there is the another opinion, based on the following information: excursion records, existing both in soils, from different climatic zones and in loesses; comparison of excursions, found at the same horizons of widely spaced sections; a rough time agreement of excursions distributed from the Ukraine up to Siberia; fixation in soil-loess complexes of the Matuyama zone, not anomalous but reversed magnetization. The summary paleomagnetic section, representing this region, has nearly 16 excursions. As has been mentioned above and in an agreement with Tretyak's suggestion (Tretyak,1983) it is quite possible that two - three closely spaced horizons, characterized by reversed or anomalous direction of the primary magnetization, represent actually one excursion of a very complicate structure. In tables such excursions are marked by dotted bracket.

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In the Zacarpathian sections (table 4) a comparison of fossil soils with time scale was based on thermoluminescence analysis (TL), carried out by V.N.Shelkoplias for rocks from the Korolevo-section. In the Korolevo-sections 14 cultural horizons are revealed, which are distributed up to alluvium (fig. 3). The Korolevo summary-section contains II excursions, most of them are traced at several excavations and widely spaced outcrops.

Ten excursions are recorded in the summary-sections of the Predurals, the Western Siberia and the Altai (tables 5 and 6). Some of "the Urals" and "the Siberian" excursions is of no doubts as from paleomagnetic point of view, so by dating accuracy (C^{14}, TL).

In connection with the fact that in the Middle Asia there are no data on Quaternary system (excluding Tajikistan), the summary paleomagnetic section for the Middle Asia is the most problematic one. At present it should be considered only as an illustration of excursion records within loess thickness, this illustration being based on the Tajikistan information, (Dodonov, Penkov, 1977), (see table 7). However, the results obtained by the International Expedition (the present monography) should be noted: in two sections within the Pritashkent region different authors, using different methods, have recorded excursions; their age defined by TL method is 100 thousand years. A lithological and thickness confirmation of these excursions is obtained in parallel excavations of the Yangiul section, as well as by time coincidence of excursions in the Yangiul and Mingtepe sections, which are located at a distance of 40 km.

Tables 8,9,10,11 well not be described in detail. They illustrate presence of excursions of different ages recorded in sedimentary rocks on vast territory of Eurasia and in bottom sediments of seas and oceans. The results, that should be considered as the unical ones are listed in table 12. All information described above is obtained on sedimentary rocks, but for the Caucasus the investigations are carried out on archaeological objects and lava flows; dating is realized with the K-Ar method. Information on excursions of the Middle Pleistocene, recorded on igneous rocks, agrees rather well with that obtained for sedimentary rocks. Studies, carried out on archaeological objects of Georgia have confirmed Folgheraiter's suggestion, made in the last century, that only 2700 years ago in Italy, Greece and now in Georgia has been revealed short-time geomagnetic field reversal.

In spite of the fact, that method of examination of GF fine structure within morainic debris is rather poor developed, the results of such investigations are of interest as there is an agreement of the data obtained by different authors and in different sections (table 13).

It is established, that morains of the Moscow glaciation possess normal magnetization only, while in morainic debris of the Dnieper, the Oka and the Don glaciations layers of both normal and reversed magnetization are observed. It is suggested, that the reversed magnetization is connected with geomagnetic field excursions (Isaev, Trukhin et al., 1978).

Summing up the USSR data one can conclude, that the maximal number of geomagnetic field excursions in the summary paleomagnetic section for a separate region is

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16 - 11, some of them have a very complicate structure. Most of these excursions is repeated at remote points: from the Carpathian to Prichernomorie and the Okhotsk Sea; from the White Sea to the Caucasus and the Middle Asia; on the Atlantic and Indian Oceans and the Mediterranean Sea.

The Middle - Late Pleistocene and Holocene are investigated in details and 8-9 excursions are revealed; the Early Pleistocene has not been studied so far (tables 9,10,11,12) or has been explored only fragmentary (tables 1,2,5,7,8,13). Within the Early Pleistocene there are revealed 4 excursions, but their dating is not sure one. A difficulty of excursion establishment in the beginning of the Early Pleistocene is connected with the fact, that sometimes it is impossible to distinguish clearly between the end of Matuyama - Brunhes transition and excursion, since the last could be interpreted as a part of transitional zone (see fig. 2).

Data, listed in tables, have been analyzed taking into account their significance. As a reliability of different excursions is not the same, each of them is given corresponding weight. The weight depends on accuracy of dating and reality of excursion definition. In turn, estimation of an excursion reality depends on the following: number of samples and stratigraphical levels used to study excursion; number of excavations and sections where excursion is found; number of excursions within the given section; laboratory examination of J_n origin; magnetic mineral composition and so on.

A histogram is plotted, illustrating a dependance of excursion number on their age, their weights being taken into account. For time-interval of 50 thousand years 4 narrow maxima are clearly seen in this histogram (fig. 4a). The first of them falls within time-span 2700 - 2900 yrs. Though this fact requires an additional confirmation , an accuracy of excursion dating, as well as the fact, that it was revealed on different objects (continental sediments, bottom silts, archaeological objects) indicates to the existence of this excursion. The second maximum falls within time-interval of II-I3 thousand years, the third and the fourth are located in time-interval of 24-26 and 40-45 thousand years correspondingly. Duration of the first maximum is 10^2 years (100 - 300 yrs), for the following three maxima this duration does not exceed 2.10^3 yrs for each of them. Time-interval of 50 - 150 thousand years is characterized by one sharp maximum within time range of 100-120 thousand years (fig. 4b), the maximum duration is sufficiently greater comparing with the previous ones.

Data available for the next long interval 150 - 730 thousand years are rather limited, accurate definitions of excursion age are not numerous excursion ages are defined approximately, using stratigraphical information, fauna, spore-pollen analysis, paleophytology examinations and the other evidences available.

The histogram showing a dependance of excursion number on their age, the excursion weights being taken into account, allows to suggest that during more than 500 years continuous excursion is going on without stationary field intervals (fig. 4c), but in fact excursions are short-time changes of GF. In accordance with data from the south of Western Siberia excursion duration in sections, occupies only 12% of the full thickness (fig. 2). Evidently, this difference represented on time-scale, would be seen still sharper, as sedimentation processes themselves have breaks. The same field patterns are seen in the other sections. In histogram (fig.

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4) 5 maxima could be outlined: 270-290, 300-380, 440-460, 500-530, 580-600 thousand years. In time-interval 320-430 thousand years, due to large error in excursion age definition, two maxima could be combined into one.

At present stage of excursion phenomenon investigation, it should not be correct to compare excursions on the base of their roughly defined ages. To clarify number of excursions within the given time-interval and to estimate their durations visual analysis of the more complete summary sections with the addition of stratigraphical, paleontological and the other information (tables 1 - 5,8) being available, should provide better results than statistical analysis.

The carried out comparisons allowed to suggest that during time-interval 580 thousand years there were at least 7 - 8 excursions.

It seems, that different excursions have different durations: some of them are short, the others, such as Blake excursion, are longer. The duration of first type - short excursions - is 10^3 yrs, the second one is longer, its duration is about 10^4 years.

During excursions of the first type geomagnetic field has one - two deviations of large amplitude with returns to the initial state. Such behaviour is similar to that of boomerang. Excursions Mono, Gotenburg, Kargapolovo belong to that type. It is possible that up to the present not all short excursions - "boomerangs" type - are revealed. This suggestion is supported by data of the Ukraine (Dudkin, 1986).

Excursions of the second type are like subchrones - events - but they have shorter duration and don't contain the complete field reversal, or this reversed field is a very short one. It is of great importance that "excursions of the same age" are revealed at different, far spaced points of the Earth's surface. It is the evidence of their global origin.

Summing up all said above, the following conclusions could be suggested: there were not less than 12 excursions during Brunhes chrone (fig. 6). The previous scheme of the Brunhes chron remains (Gurarij et al. 1983; Fotiadi, Pospelova, 1982), but with certain supplements (excursion Etrussia) and improvements (proposed combination of 4 excursions (Biwa I and Jamaica and the Biwa II and Chagan-Dniepr) into two types with complexe structure. Age of these excursions is estimated only approximatly especially for the Early and Middle Pleistocene.

Any periodicy in excursion occurences during Brunhes chrone is not revealed, what can be connected with the dating errors. Excursions occured over intervals of 50, 60 and up to 100 thousand years. Evidently, if there is any quasiperiod, this period would be less than 100 thousand years. During Late Pleistocene, where age - estimates are accurate enough, excursion periodicy is 14 - 16 thousand years (fig. 5).

3. Relation between the geomagnetic field excursions and the other Earth's phenomena

Problems of relations between the geomagnetic field variations and the other Earth's phenomena have discussed more than once. (Jacobs, 1981) mentioned existence of correlation between frequency of the geomagnetic reversal occurence and the Earth's heat flow variations during the last 150 million years, what may indicate to relation between processes in upper mantle and in the Earth's outer core. Correlations are observed between hyperzones of polarity intervals and tectonic processes, recur-

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rence of the field intensity and geological eras (Bolshakov, Solodovnikov, 1981), long-period geomagnetic field variations and climatic changes (Bucha et al., 1977).

Naturelly, relations of geomagnetic field excursions with different changes within biosphere and geosphere are investigated too. The greatest attention is drown to correlation between the geomagnetic excursions and climatic changes. Such investigations are carried out on concrete sections, containing geomagnetic field excursions. The perfect example is study of bottom deep-sea columns from the northern part of the Pacific Ocean; this study envelopes the last ~ 450 thousand years. By studies of this kind rock magnetic parameters, In values, and inclinations are compared with oxygen-isotope curves and patterns of climatic changes reflected by variations of the temperature-indicative foraminifera Globorotalia menardi (Wollin et al., 1971). Analogous comparisons are carried out with columns from the Caribian and the Mediterranian Seas. The clear correlation between corresponding curves is revealed as within each region, so between far-spaced ones. The largest In values are associated with temperature falls, while sharp changes of inclination up to the reverse ones (excursions) correlate with temperature rises. This pattern of correlation is characteristic for all the mentioned basins during the last ~ 450 thousand years. On the other hand, in accordance with the data on oceanic columns and continental sedimentations, geomagnetic field of weak intensity during Matuyama-Brunhes reversal correlates rather well with cold climate (Adamenko et al., 1981).

In sections of continental sediments during the Brunhes chrone excursions are recorded as in soil horizons, so in loess and glacial deposits - moraines.

Besides examination of correlative relations between excursions and climatic changes using separate sections, such studies are carried out on the global scale, too. Times of excursion occurences, corrected arbitrary by Rampino, are compared with changes of the Earth's orbite eccentricity. Close coincidence between excursions and peaks of eccentricity curve suggests a causal relation between these phenomena (Rampino, 1981). A model of excursion mechanism is suggested, though rather speculative one. In accordance with this model a mechanism of excursion modulation is related with the changes in the Earth's core convection, the cause of which is an increase of difference in procession velocities and moments of the core and mantle near maximum of oscillations of the Earth's orbite eccentricity.

Thus there is correlation between the parameters of the Earth's orbit, magnetism and climate. However, any global comparisons would be speculative ones, till the excursion dating become accurate enough.

Such comparisons make sense only for the last 120 thousand years, when excursion ages are rather accurately estimated. Comparisons of excursion pecularities depending on time with temperature rises and falls indicate to the fact, that within the last 120 thousand years each excursion correlated with temperature rise (Arslanov, 1985) , (see fig. 6). The same picture is observed for separate columns of the Middle-Late Pleistocene. An existence of correlation between geomagnetic field excursions and climatic changes indicates to relation of the processes in the Earth's core and the near Earth's space.

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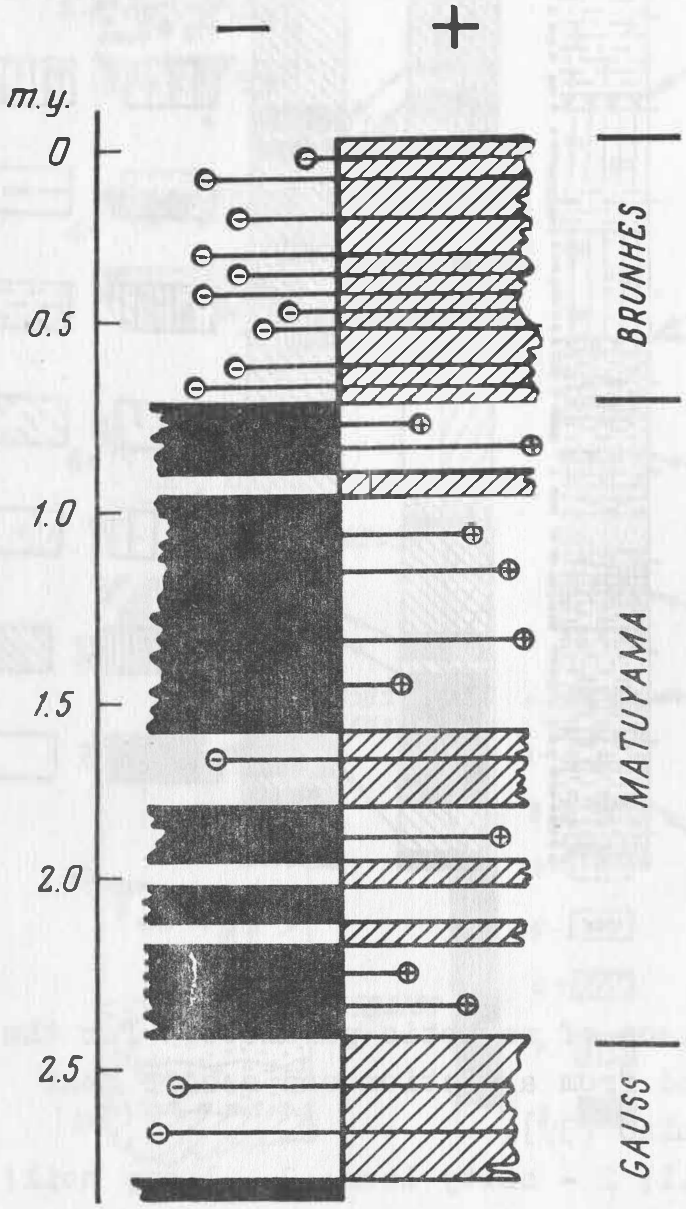

Fig. 1. Schematic representation of the geomagnetic field changes during the last 3 mln yrs.

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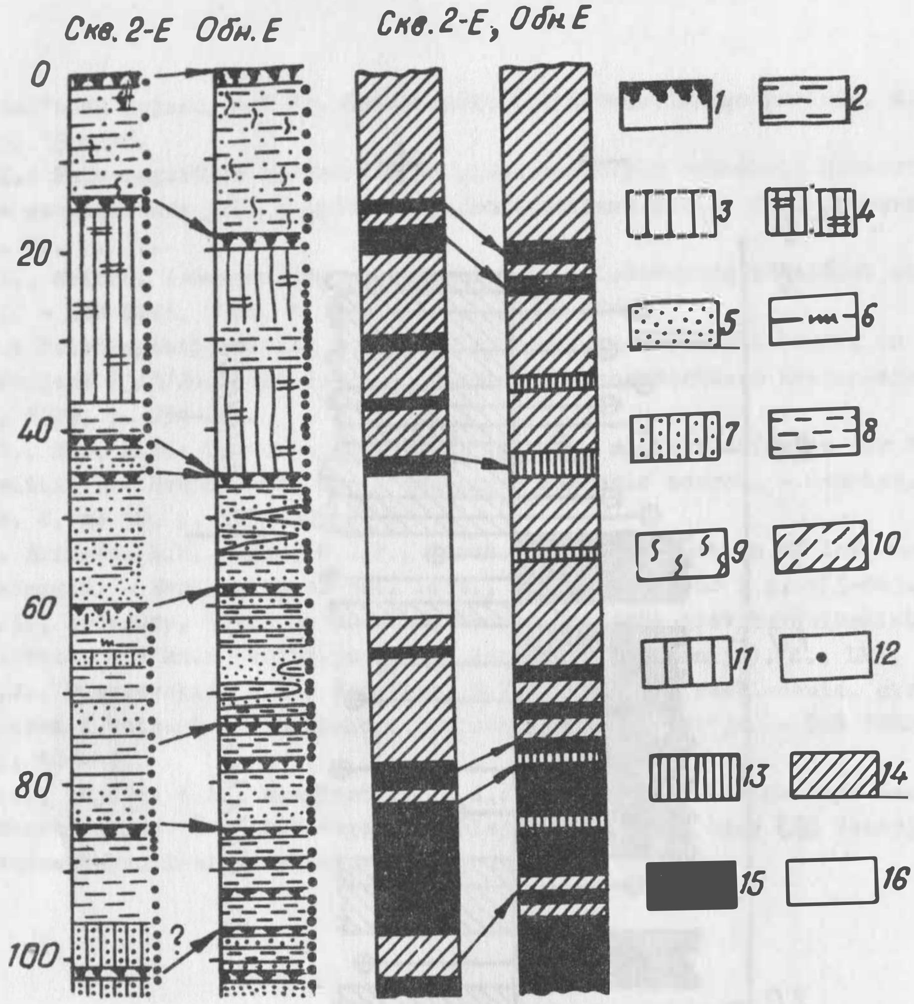

Fig. 2. Comparison of magnetic parameters for the rocks obtained from a section and a bore near v. Elunino [39].

1 - soil; 2 - silty loam; 3 - loamy soil; 4 - clay; 5 - sand; 6 - humus; 7 - sandy clay; 8 - silty loam; 9 - loessial soil; 10 - aleurite; 11 - correlation of lithologic strata and excursions; 12 - sites of sampling; 13-15 - magnetic horizons; 13 - with anomalous Jn; 14 - with normal Jn; 15 - with negative inclination of Jn; 16 - not examined part of section.

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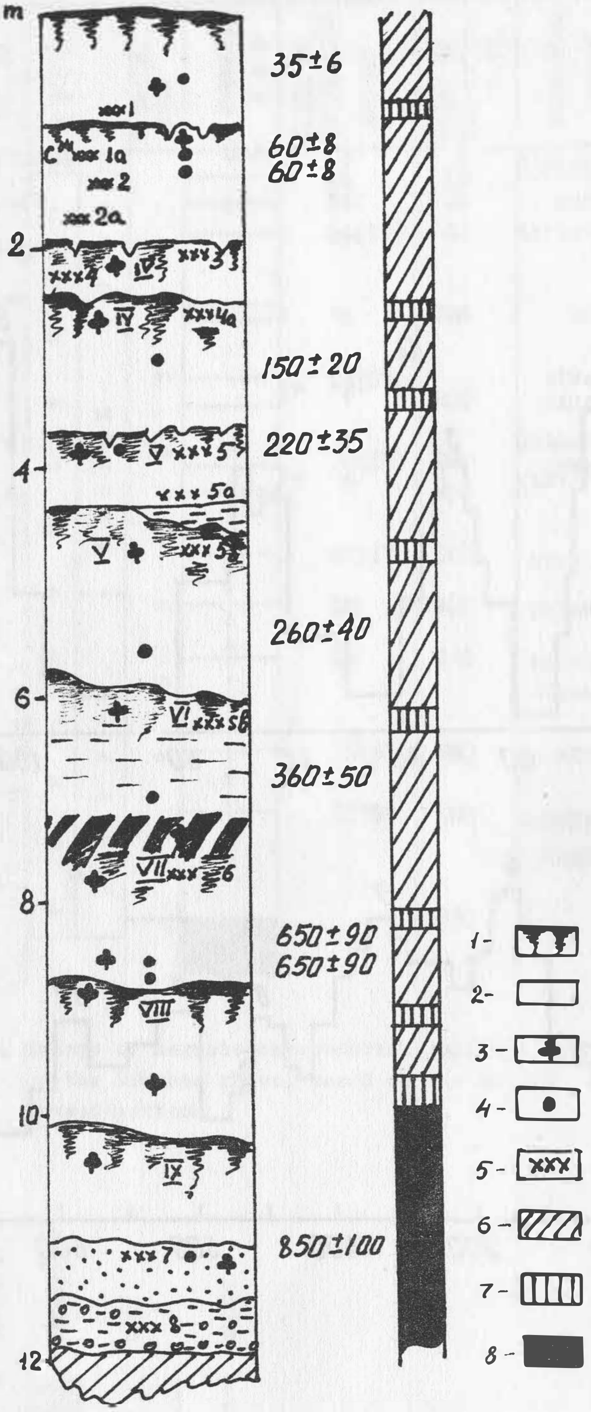

Fig. 3. Lithological column and paleomagnetic section Korolevo (Transcarpathian Mountains) [2]
1 - fossil soil; 2 - loam; 3 - spore-pollen analysis;
4 - thermoluminescence analysis; 5 - cultured stratum
6 - normal Jn; 7 - reversed Jn.

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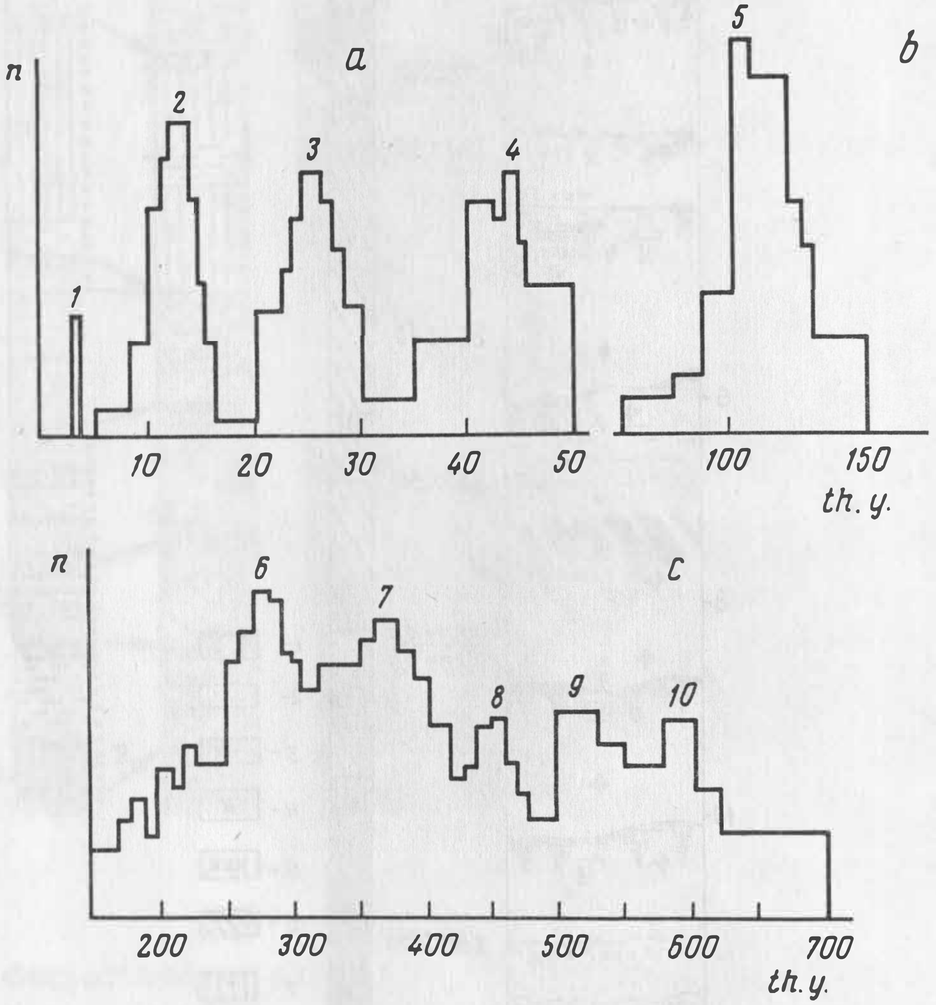

Fig. 4. Histogram of distribution of the excursion number depending on the age.

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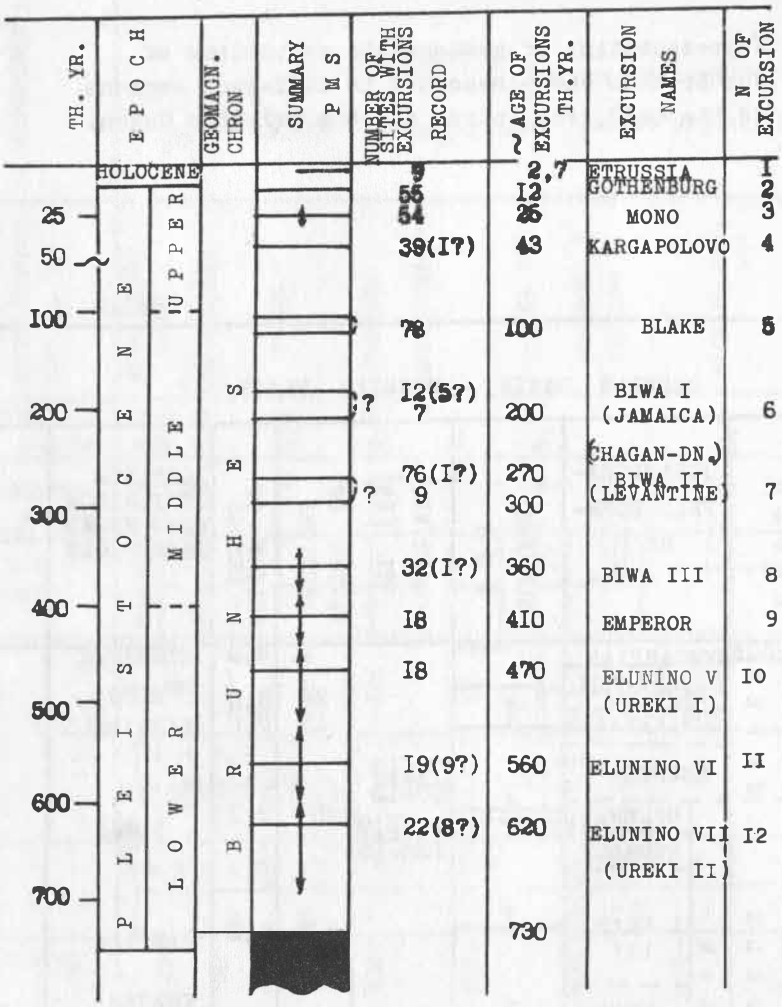

Fig. 5. Scheme of magneto-chronostratigraphical scale of the Brunhes chron, based on the Soviet investigations

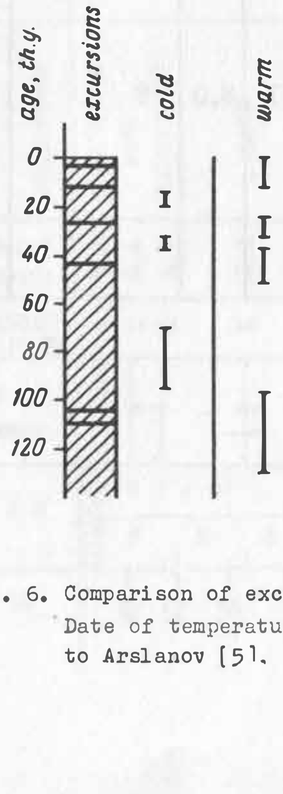

Fig. 6. Comparison of excursion age with paleoclimatic data. Date of temperature fall and rise are taken according to Arslanov [5].

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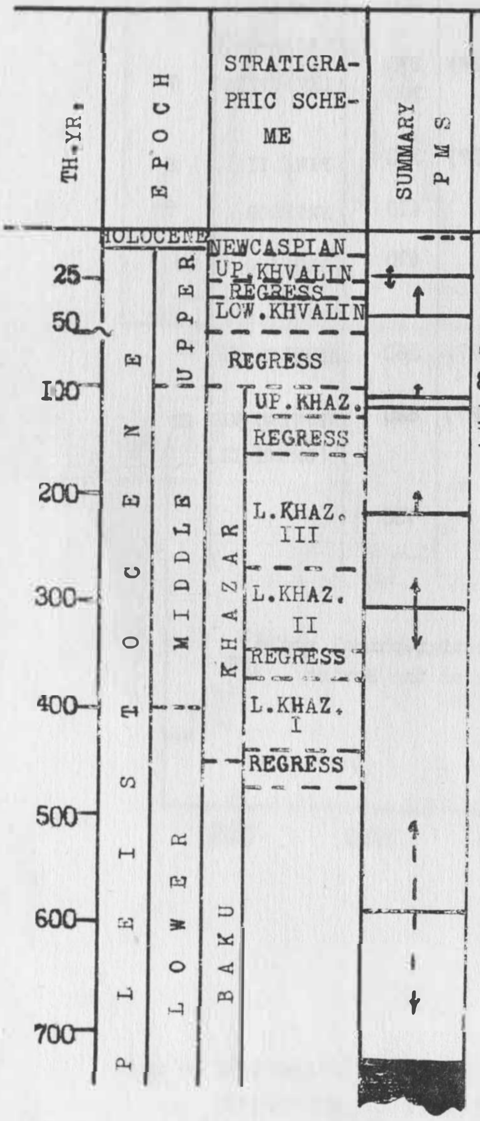
Tab. 1 - 13. Representation of geomagnetic excursions of the Brunhes chron recorded in different regions of the USSR, the Indian and the Atlantic Ocean.

TABLE I

CASPIAN BASIN , RUSSIAN PLAIN



STRATIGRAPHIC SCHEME	TH.YR. TL [69]	NUMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
NEWCASPIAN		I	2,0	ETRUSSIA	EREMIN,MOLCSTOVSKY [26] ,GURARY, NECHAEVA, TRUBIKHIN [21] , NECHAEVA, TRUBIKHIN [44], GLEYZER,DEDKOV,JASONOV [16] ,PISAREVSKY [33], FAUSTOV,BOL'SHAKOV [63] ,ALIKHANOV,ISMAIL-ZADE a.o.[3],GONNOV,LOPATNIKOV [19], GONNOV [18] ,
UP.KHVALIN		24	8,0	MONO	
LOW.KHVALIN		15	7,0	KARGAPOLOVO	
REGRESS / UP.KHAZ.	74±I0 80+I0 I00±I7 I26+I5	I8	7,2	BLAKE	
L.KHAZ. III		5	5,2	JAMAIKA	
L.KHAZ. II		6	5,4	CHAGAN-DNIEPER	
BAKU		I	3,0	?	

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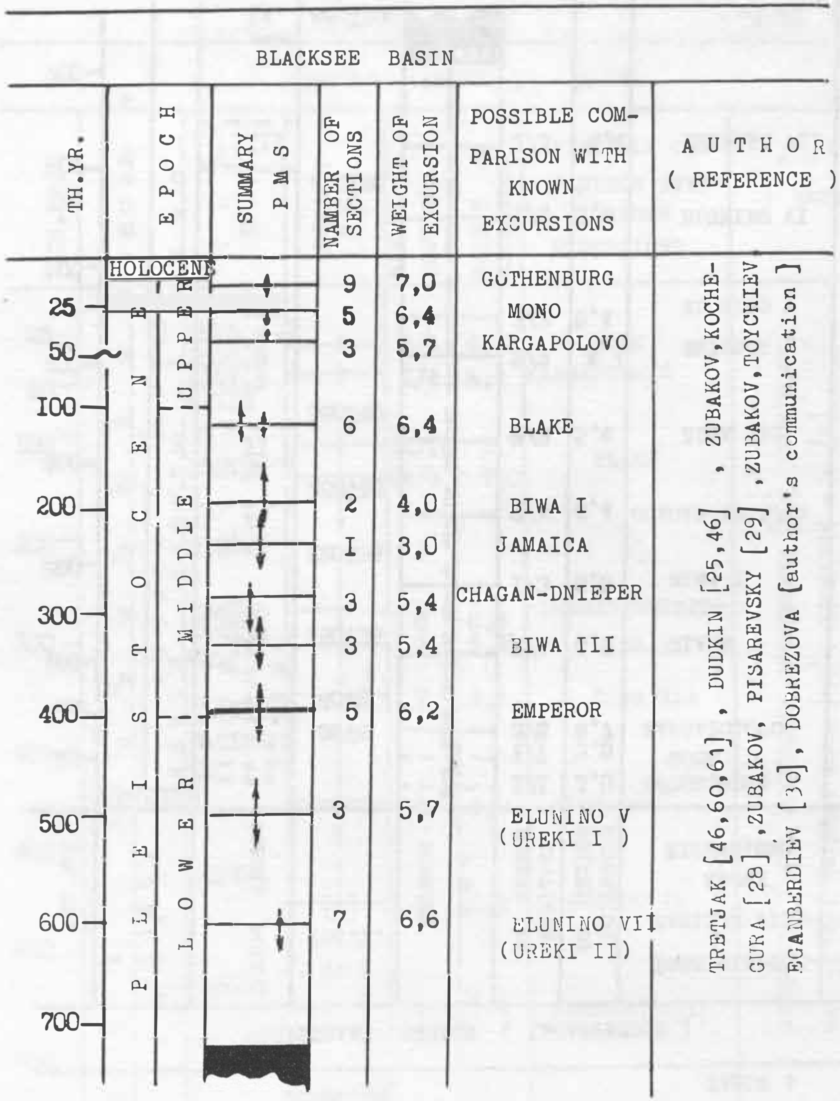
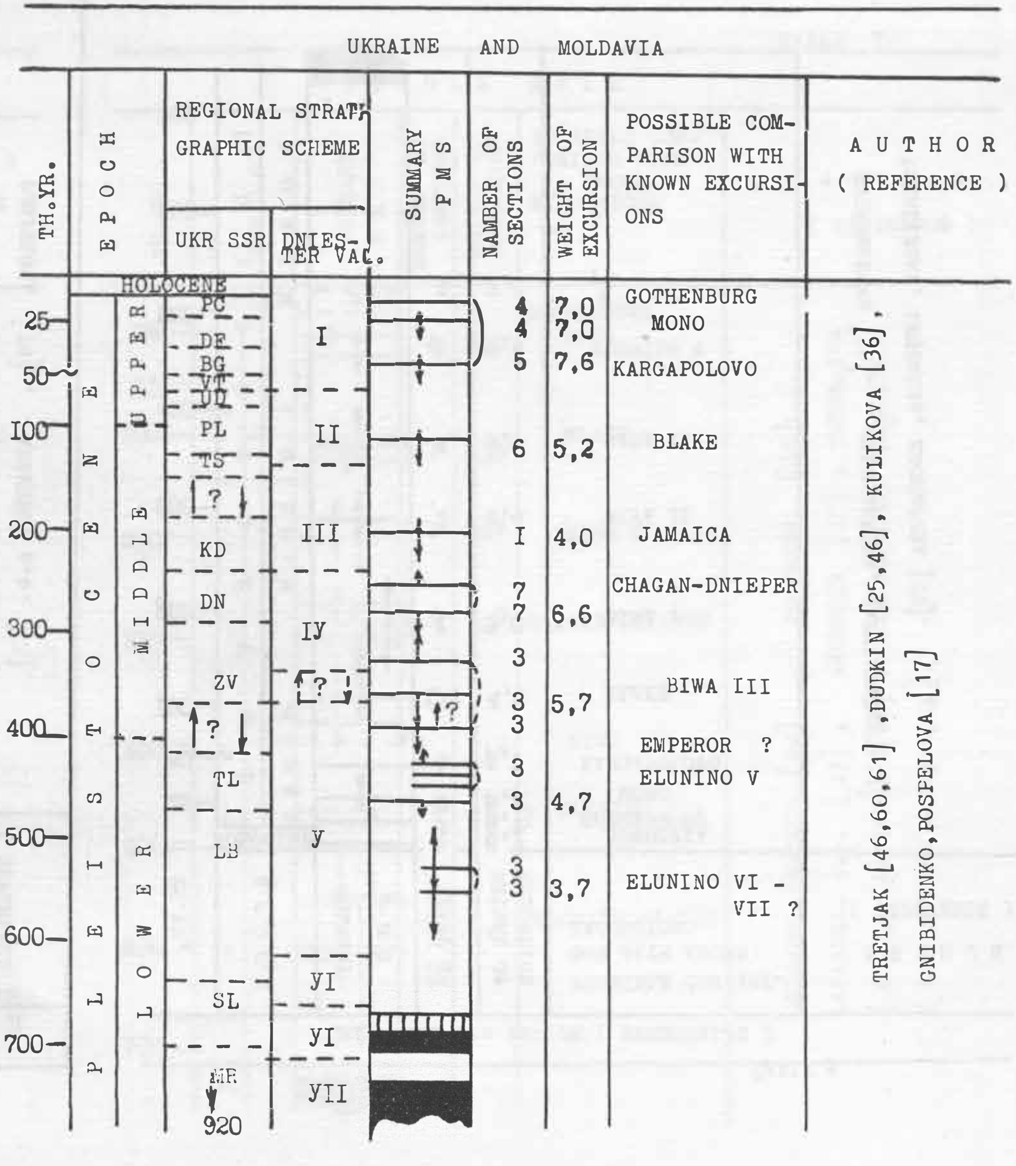
TABLE 2



BLACKSEE BASIN

TH.YR.	EPOCH		SUMMARY PMS	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE			9	7,0	GOTHENBURG	TRETJAK [46,60,61] , DUDKIN [25,46] , ZUBAKOV,KOCHEGURA [28],ZUBAKOV, PISAREVSKY [29] ,ZUBAKOV,TOYCHIEV, EGANBERDIEV [30], DOBREZOVA (author's communication]
25	PLEISTOCENE	UPPER		5	6,4	MONO	
50				3	5,7	KARGAPOLOVO	
100				6	6,4	BLAKE	
200		MIDDLE		2	4,0	BIWA I	
				I	3,0	JAMAICA	
				3	5,4	CHAGAN-DNIEPER	
300				3	5,4	BIWA III	
400				5	6,2	EMPEROR	
500		LOWER		3	5,7	ELUNINO V (UREKI I)	
600				7	6,6	ELUNINO VII (UREKI II)	
700							

TABLE 3



UKRAINE AND MOLDAVIA

TH.YR.	EPOCH		REGIONAL STRATIGRAPHIC SCHEME: UKR SSR	REGIONAL STRATIGRAPHIC SCHEME: DNIESTER VAL.	SUMMARY PMS	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE					4	7,0	GOTHENBURG	TRETJAK [46,60,61] ,DUDKIN [25,46], KULIKOVA [36], GNIBIDENKO,POSPELOVA [17]
25	PLEISTOCENE	UPPER	PC DE	I		4	7,0	MONO	
50			BG VT UD			5	7,6	KARGAPOLOVO	
100			PL TS	II		6	5,2	BLAKE	
		MIDDLE	?						
200			KD	III		I	4,0	JAMAICA	
			DN			7 7	6,6	CHAGAN-DNIEPER	
300			ZV	IУ ?		3 3 3	5,7	BIWA III	
400		LOWER	? TL		?	3		EMPEROR ? ELUNINO V	
						3	4,7		
500			LB	У		3 3	3,7	ELUNINO VI - VII ?	
600			SL	УI					
700			MR 920	УI УII					

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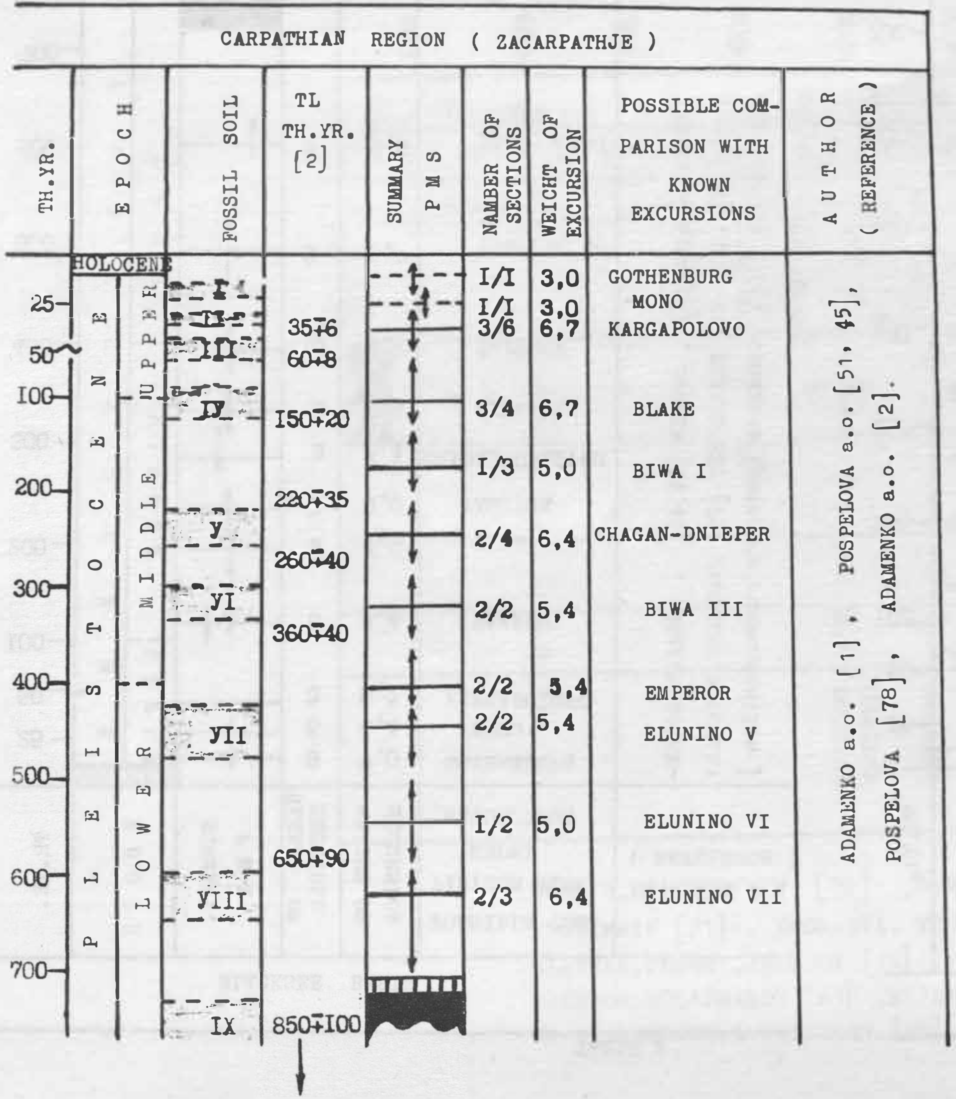
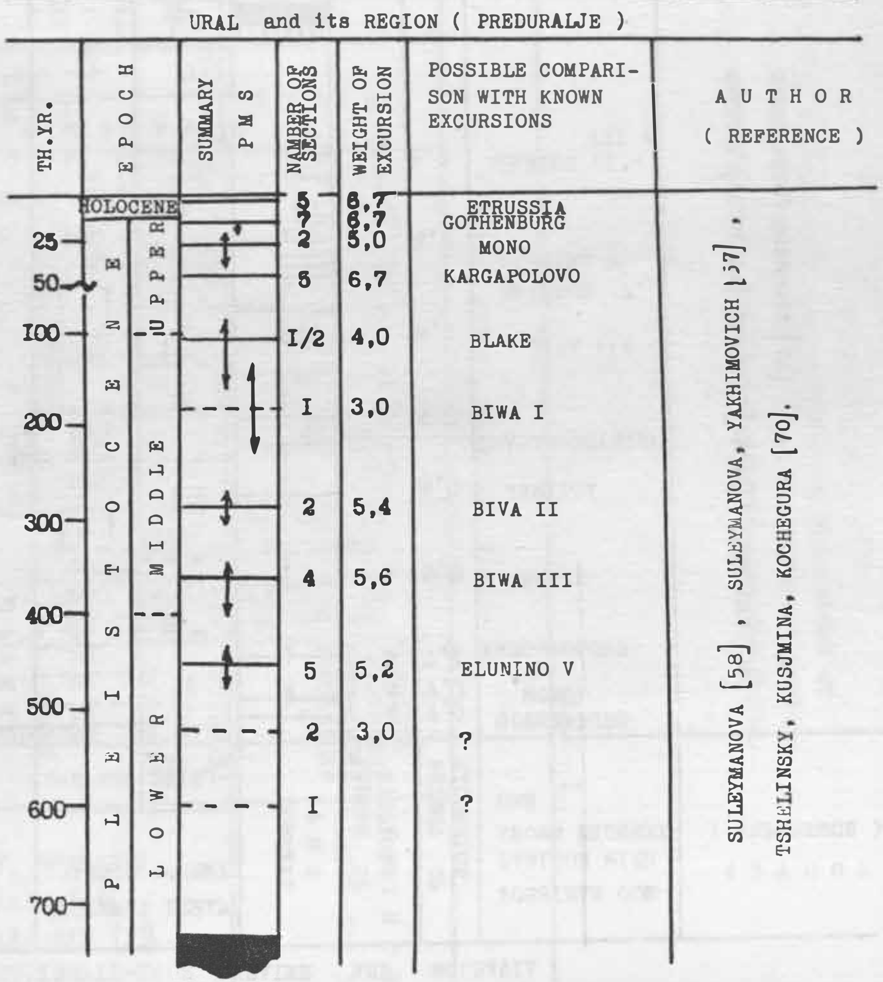
TABLE 4



CARPATHIAN REGION (ZACARPATHJE)

TH.YR.	EPOCH	FOSSIL SOIL	TL TH.YR. [2]	NAMBER OF SECTIONS	WEICHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE						ADAMENKO a.o. [1], POSPELOVA a.o. [51, 45], POSPELOVA [78], ADAMENKO a.o. [2].
	PLEISTOCENE UPPER	I		I/I	3,0	GOTHENBURG	
25		II		I/I	3,0	MONO	
			35∓6	3/6	6,7	KARGAPOLOVO	
50		III	60∓8				
100	MIDDLE	IУ	150∓20	3/4	6,7	BLAKE	
				I/3	5,0	BIWA I	
200			220∓35				
		У		2/4	6,4	CHAGAN-DNIEPER	
			260∓40				
300		УI		2/2	5,4	BIWA III	
			360∓40				
400	LOWER			2/2	5,4	EMPEROR	
		УII		2/2	5,4	ELUNINO V	
500							
				I/2	5,0	ELUNINO VI	
			650∓90				
600		УIII		2/3	6,4	ELUNINO VII	
700							
		IX	850∓100				

TABLE 5



URAL and its REGION (PREDURALJE)

TH.YR.	EPOCH	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE	5	6,7	ETRUSSIA	SULEYMANOVA [58], SULEYMANOVA, YAKHIMOVICH [57], TSHELINSKY, KUSJMINA, KOCHEGURA [70].
	PLEISTOCENE UPPER	7	6,7	GOTHENBURG	
25		2	5,0	MONO	
50		5	6,7	KARGAPOLOVO	
100	MIDDLE	I/2	4,0	BLAKE	
		I	3,0	BIWA I	
200					
		2	5,4	BIVA II	
300					
		4	5,6	BIWA III	
400	LOWER				
		5	5,2	ELUNINO V	
500					
		2	3,0	?	
600		I		?	
700					

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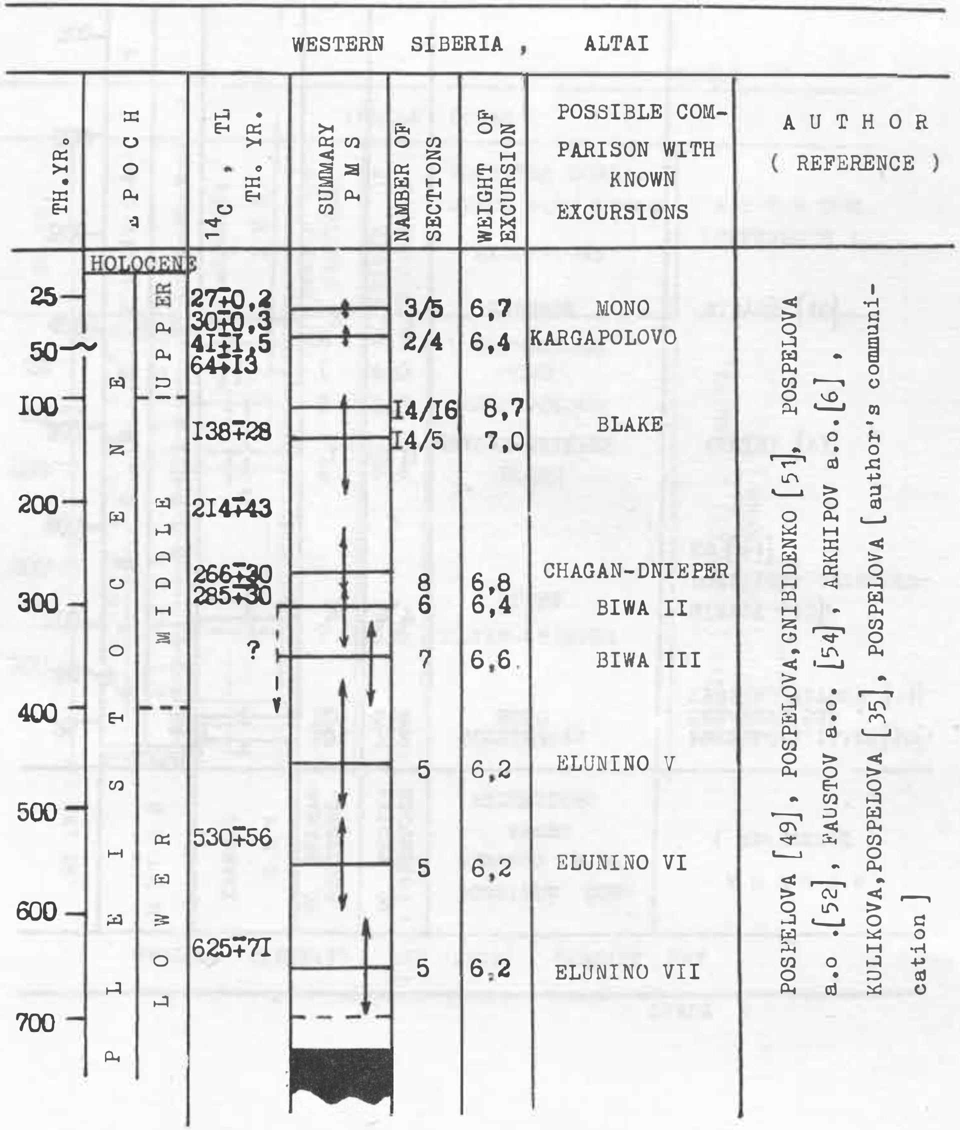
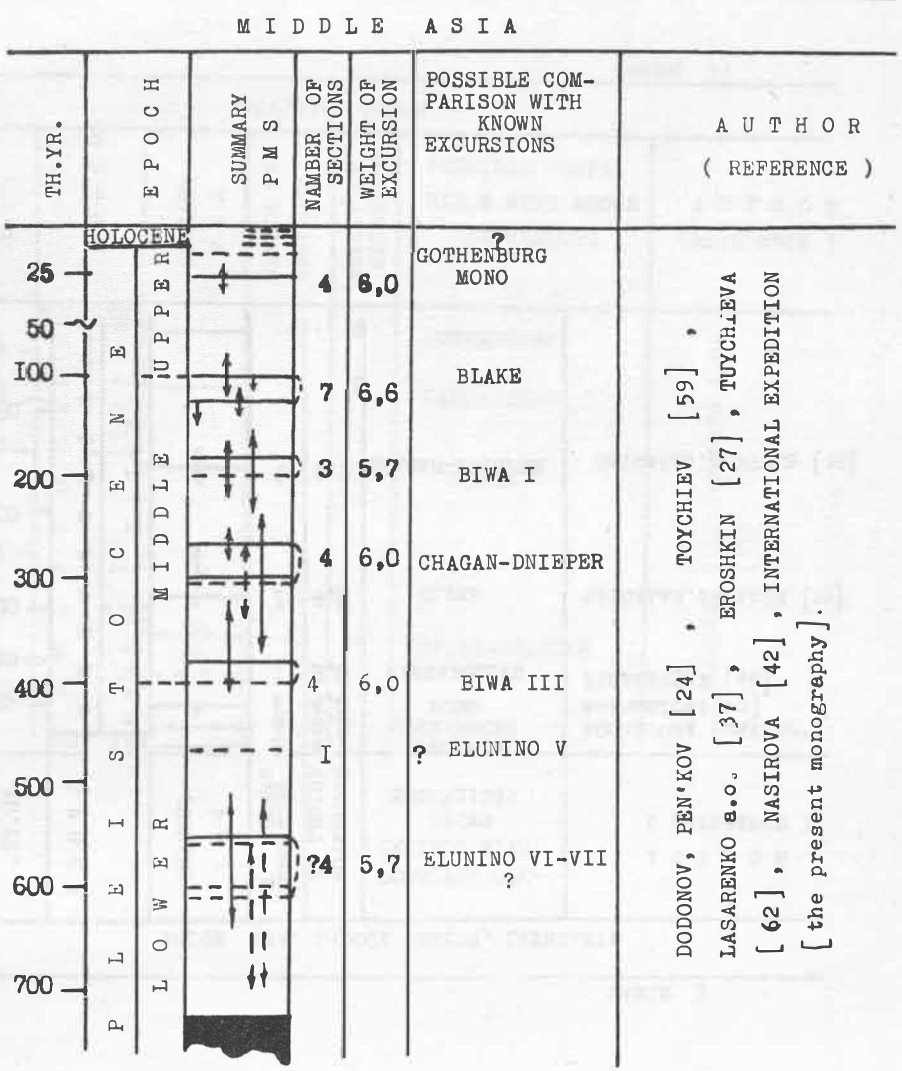
TABLE 6



WESTERN SIBERIA , ALTAI

TH.YR.	EPOCH	^{14}C , TL TH. YR.	SUMMARY P M S	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE						POSPELOVA [49], POSPELOVA,GNIBIDENKO [51], POSPELOVA a.o .[52], FAUSTOV a.o. [54], ARKHIPOV a.o.[6] , KULIKOVA,POSPELOVA [35], POSPELOVA [author's communication]
25	PLEISTOCENE UPPER	27±0,2 30±0,3		3/5	6,7	MONO	
50		4I±I,5 64±I3		2/4	6,4	KARGAPOLOVO	
100	PLEISTOCENE MIDDLE	I38±28		I4/I6 I4/5	8,7 7,0	BLAKE	
200		2I4±43					
300		266±30 285±30		8 6	6,8 6,4	CHAGAN-DNIEPER BIWA II	
		?		7	6,6	BIWA III	
400	PLEISTOCENE LOWER			5	6,2	ELUNINO V	
500		530±56		5	6,2	ELUNINO VI	
600		625±7I		5	6,2	ELUNINO VII	
700							

TABLE 7



M I D D L E A S I A

TH.YR.	EPOCH	SUMMARY P M S	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE					DODONOV, PEN'KOV [24] , TOYCHIEV [59] , LASARENKO a.o. [37] , EROSHKIN [27] , TUYCHIEVA [62] , NASIROVA [42] , INTERNATIONAL EXPEDITION [the present monography].
25	PLEISTOCENE UPPER		4	6,0	? GOTHENBURG MONO	
50						
100	PLEISTOCENE MIDDLE		7	6,6	BLAKE	
200			3	5,7	BIWA I	
300			4	6,0	CHAGAN-DNIEPER	
400	PLEISTOCENE LOWER		4	6,0	BIWA III	
			I		? ELUNINO V	
500						
600			?4	5,7	ELUNINO VI-VII ?	
700						

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TABLE 8

EASTERN SIBERIA, FAR EAST, OKHOTSK SEA

TH. YR.	EPOCH	SUMMARY PMS	NUMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE					
25	PLEISTOCENE UPPER		18 10	7,2 5,4	GOTHENBURG MONO	POSPELOVA, IL'EV [50], SEMAKOV [55] VIRINA, SVITOCH [14]
50						
100	PLEISTOCENE MIDDLE		3	3,7	BLAKE	MINYUK [40]. POSPELOVA, GNIBIDENKO [51]
200						
300			I	2,0	CHAGAN-DNIEPER	VIRINA [13]
400	PLEISTOCENE LOWER		2	4,4	EMPEROR ?	MINYUK [40]
500						
600						
700						

TABLE 9

WHITE SEA, LADOGA REGION, LITHUANIA

TH. YR.	EPOCH	SUMMARY PMS	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE		3	4,7	ETRUSSIA	
	PLEISTOCENE UPPER		4	6,0	GOTHENBURG	KOCHEGURA [author's communication]
25			I	4,0	MONO	
50			I	3,0	KARGAPOLOVO	PISAREVSKY [48]
100	PLEISTOCENE MIDDLE		I	4,0	BLAKE	GAIGALAS, PEVZNER [15]
200			I	4,0	CHAGAN-DNIEPER	GAIGALAS, PEVZNER [15]
300						

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TABLE 10

INDIAN OCEAN

TH.YR.	EPOCH		SUMMARY PMS	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE		↕	12	6,9	GOTHENBURG	TRETJAK [20,60,61], BAGINA, BESRUKOV, DEMIDENKO [7], DEMIDENKO [22].
25	PLEISTOCENE	UPPER	↕	I	4,0	MONO	
50			↕	3	5,7	KARGAPOLOVO	
100			↕	2	5,4	BLAKE	
200		MIDDLE					
			↕	7	6,6	CHAGAN-DNIEPER	
300							
			↕	8	6,8	BIWA III	

TABLE 11

ATLANTIC OCEAN

TH.YR.	EPOCH		SUMMARY PMS	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
	HOLOCENE			4	6	GOTHENBURG	TRETJAK, VIGILYANSKAYA a.o. [47]
25	PLEISTOCENE	UPPER					
50				4	6	KARGAPOLOVO	
100							
		MIDDLE	↕	4	6	BLAKE	
200							
			↕	4	6	CHAGAN-DNIEPER	
300							

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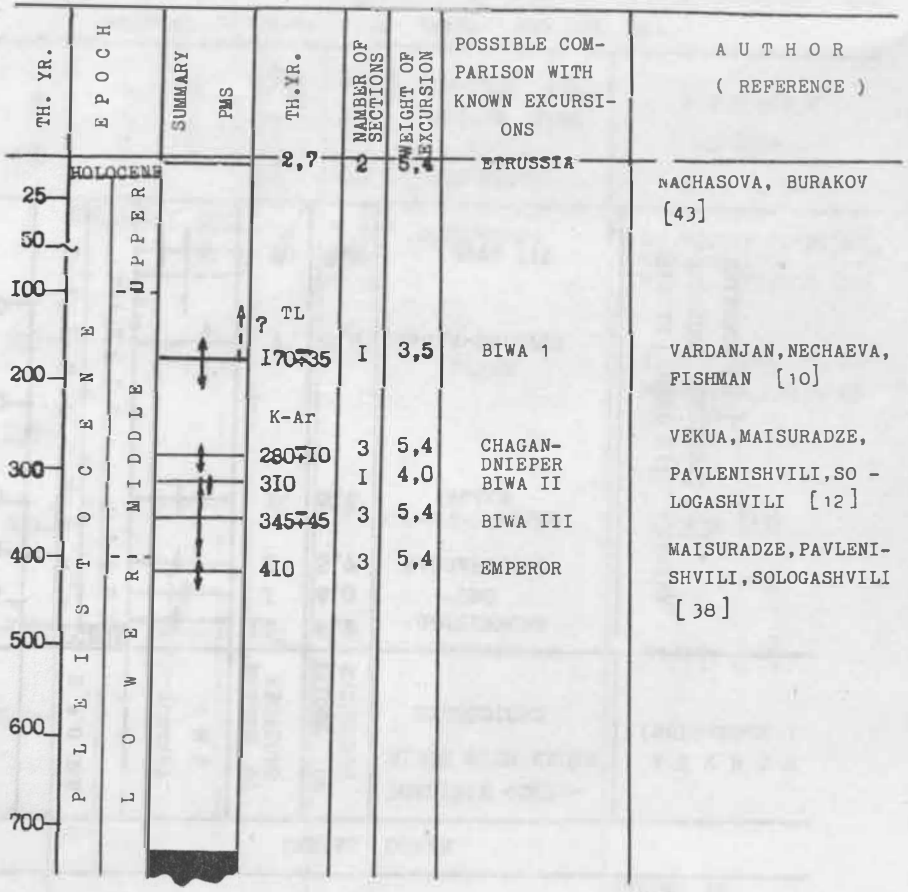
TABLE 12

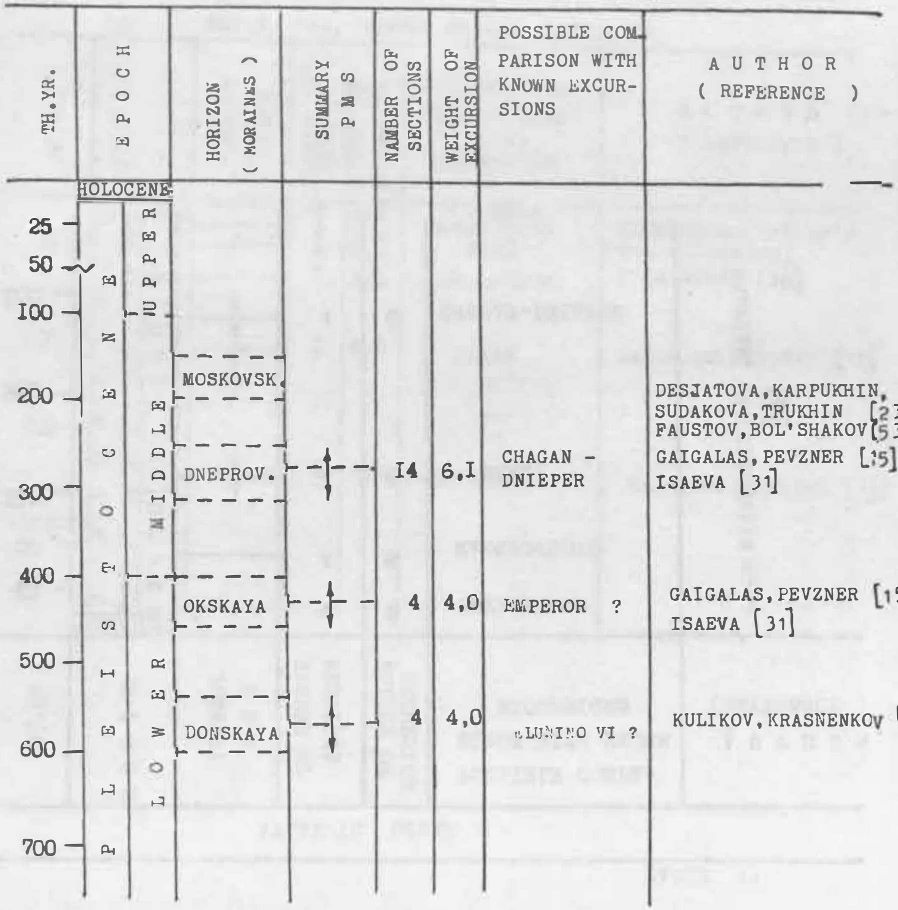
C A U C A S U S



TH. YR.	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
2,7	2	5,4	ETRUSSIA	NACHASOVA, BURAKOV [43]
TL 170∓35	I	3,5	BIWA 1	VARDANJAN, NECHAEVA, FISHMAN [10]
K-Ar 280∓IO	3	5,4	CHAGAN-DNIEPER	VEKUA, MAISURADZE, PAVLENISHVILI, SOLOGASHVILI [12]
3IO	I	4,0	BIWA II	
345∓45	3	5,4	BIWA III	
4IO	3	5,4	EMPEROR	MAISURADZE, PAVLENISHVILI, SOLOGASHVILI [38]

TABLE 13

RUSSIAN PLAIN (MORAINES)



HORIZON (MORAINES)	NAMBER OF SECTIONS	WEIGHT OF EXCURSION	POSSIBLE COMPARISON WITH KNOWN EXCURSIONS	AUTHOR (REFERENCE)
MOSKOVSK.				
DNEPROV.	I4	6,I	CHAGAN - DNIEPER	DESJATOVA, KARPUKHIN, SUDAKOVA, TRUKHIN [23] FAUSTOV, BOL'SHAKOV [53], GAIGALAS, PEVZNER [15] ISAEVA [31]
OKSKAYA	4	4,0	EMPEROR ?	GAIGALAS, PEVZNER [15] ISAEVA [31]
DONSKAYA	4	4,0	LUNINO VI ?	KULIKOV, KRASNENKOV [34]

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THE ANALYSIS OF THE NATURAL REMANENT MAGNETIZATION COMPONENTS OF SEDIMENTARY ROCKS IN TRANSITIONAL ZONES

A.N.Khramov

Paleomagnetic studies show that a simple model of natural remanent magnetization J_n of sedimentary rocks treated as a sum of the primary and secondary components especially when applied to old rocks is only a first approximation and as such insufficient for understanding of paleosecular variations and reversals of the geomagnetic field and cannot be also applied to the solution of magnetostratigraphic problems in detail. A more general model incorporates some temporal components J_n, viz., synchronous (fast primary), orthochronous (slow primary), metachronous (ancient secondary), and recent to mention a few /2/ .

Two important questions arise what is the occurrence of "intermediate" age NRM-component in particular in redbeds as an important object of paleomagnetic studies and what is the contribution of the components in the record of geomagnetic reversals. One should analyze a lot of data available to solve the problems so we limit ourselves to special cases. In this respect of great interest are the Ordovician and Upper Cambrian redbeds of the southern Siberian platform where joint investigations were carried out by the paleomagnetologists within the scope of the Comission of the Academies of sciences of the Socialist Countries for Planetary geophysical Research (KAPG) /3/ . The study of the rocks shows that despite similarity of magnetic properties caused by fine-dispersed hematite and hydroxides incorporated into pigment and small grains of hematite (specularite) and magnetite of a silt fraction, there is a drastic difference in J_n component composition /3/ . The redbeds of the southern Siberian platform are dominated by primary magnetization while farther north in trappean magmatic provinoe is heavily obscured and even replaced by magnetization of Early Mesozoic age /1/ .

The study carried out during the joint KAPG-project have not solved the problem about the relationship between the slow and fast components involved in the primary magnetization of the Ordovician-Upper Cambrian redbeds in the southern Siberian platform and have not also assessed the rate at which the magnetization is formed.

The paper presents some data pertinent to the solution of the problem based on the NRM-component analysis using detailed step-wise demagnetization of rock samples. The results obtained during joint studies and listed in /3/ were added by the new experiments data from the samples remained in our disposal.

During the joint project rocks were sampled from outcrops at the Lena River near the villages of Chertovskaya, Polovinka, and Khamra. Some samples were collected from the transsitional beds separating zones of different magnetic polarity. Many rock specimens were subject to detailed step-wise thermal demagnetization up to 500-600°C or alternating field demagnetization up to 64 kA/m and in some cases up to 120 kA/m.

Zijderveld diagrams and stereonets of removed and remained vectors show the presence of three NRM-components - normal, reversed, and intermediate (transitional) polarities - in transitional or close to them beds (Fig. 1 and 2). We have not observed that components are related to certain stability intervals: "lagging" component both in N → R transitions and in R → N transitions may be recognized in the beginning, middle or in the end of the demagnetization process. However, transitional directions are rare at the final stages of demagnetization.

Figure 3 shows the better known N → R transition in the section of the upper Verkholensk Formation at Khamra village, here, transitional directions occur throughout the spectrum of NRM-component stability. An interval of transitional directions based on a net mag-

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netization (to be exact, its non-viscous part) accounts for about 90 cm, however, the directions in various components occur over a thickness of 2 m. It is noteworthy that reverse polarity components starting from a level of 2.2 m where they cover the entire stability spectrum "penetrate" to a depth of about 2 m. It is likely that time corresponding to accumulation of 2 m of sediments - at maximum in this case 150 Ka /1/ is a typical time interval necessary for the termination of the post-depositional magnetization process, i.e. for the formation of orthochronous detrial and chemical magnetization.

Of interest also are two time estimates, viz., duration of geomagnetic reversal and time corresponding to a shift of N and R - zone boundaries due to post-depositional magnetization. The former may be an interval between last events of normal polarity and transitional directions, in this case levels 1.7 and 2.2 m. In other words, we get time interval during which geomagnetic field reversal takes place of 35-40 Ka. The boundaries of N- and R- zones in magnetostratigraphy are drawn at a level equivalent to a zero paleolatitude Φ_α of a virtual geomagnetic pole extimated from typical magnetization. In this case $\Phi_\alpha = 0$ corresponds to declination $D = 230^{\circ}$, i.e. a level of 1.3 m (Fig.3). The level is 0.4 m below the level of normal polarity disappearance and 0.9 m below that of transitional polarity. Hence the middle part of a N → R transition is determined in a section (according to characteristic magnetization) 0.6-0.7 m below its actual position, i,e. a shift of a magnetostratigraphic boundary is at 50 Ka.

A later, metachronous, magnetization known in the Siberian platform only from trappean magmatic province is a predominant component in the Ordovician redbeds of that place and occupies often the entire spectrum of blocking temperatures and fields. NRM-component with a peculiar Ordovician direction is observed in some cases only at a temperature close to the Curie temperature for hematite.

Estimates of peculiar time in the formation of slow component of primary magnetization of redbeds and the effect of the component on a record pattern of the geomagnetic field reversal is undoubtedly ranked as a special case of the last geomagnetic reversal during the Late Cambrian and its record in sections of the Verkholensk Formation on the southern Siberian platform. The estimates, however, are similar those obtained by deep-sea cores investigations in particular, at boundaries of magnetic zones and to those obtained in laboratory and by numerical simulation /4/ . Therefore we may draw some general conclusions. First, the NRM-component analysis of all the samples chosen seems necessary both when a fine temporal structure of the geomagnetic field is studied and, in particular, of the field reversals in sections of old redbeds and for better understanding of magnetostratigraphy of the latter. Second, one should take into account a "lengthening" of the record of a reversal process by the assessment of its duration and moreover it is assumed that "a transitional regime of geomagnetic field" based on a characteristic magnetization is taken to be a mode of record and re-record by a sediment of some transitional states of the field whose time sequence remained unknown. Finally, diachronism of magnetostratigraphic boundaries recognized using primary (on the basis of all the characteristics) magnetization of red terrigenous rocks may be tens of thousands years and to decrease the diachronism the boundaries should be placed at a level of a complete absence of the earlier polarity in all physical components of the primary magnetization.

The author is very grateful to all the participants of the joint paleomagnetic studies under the auspecies of KAPG whose results allowed us to do this work.

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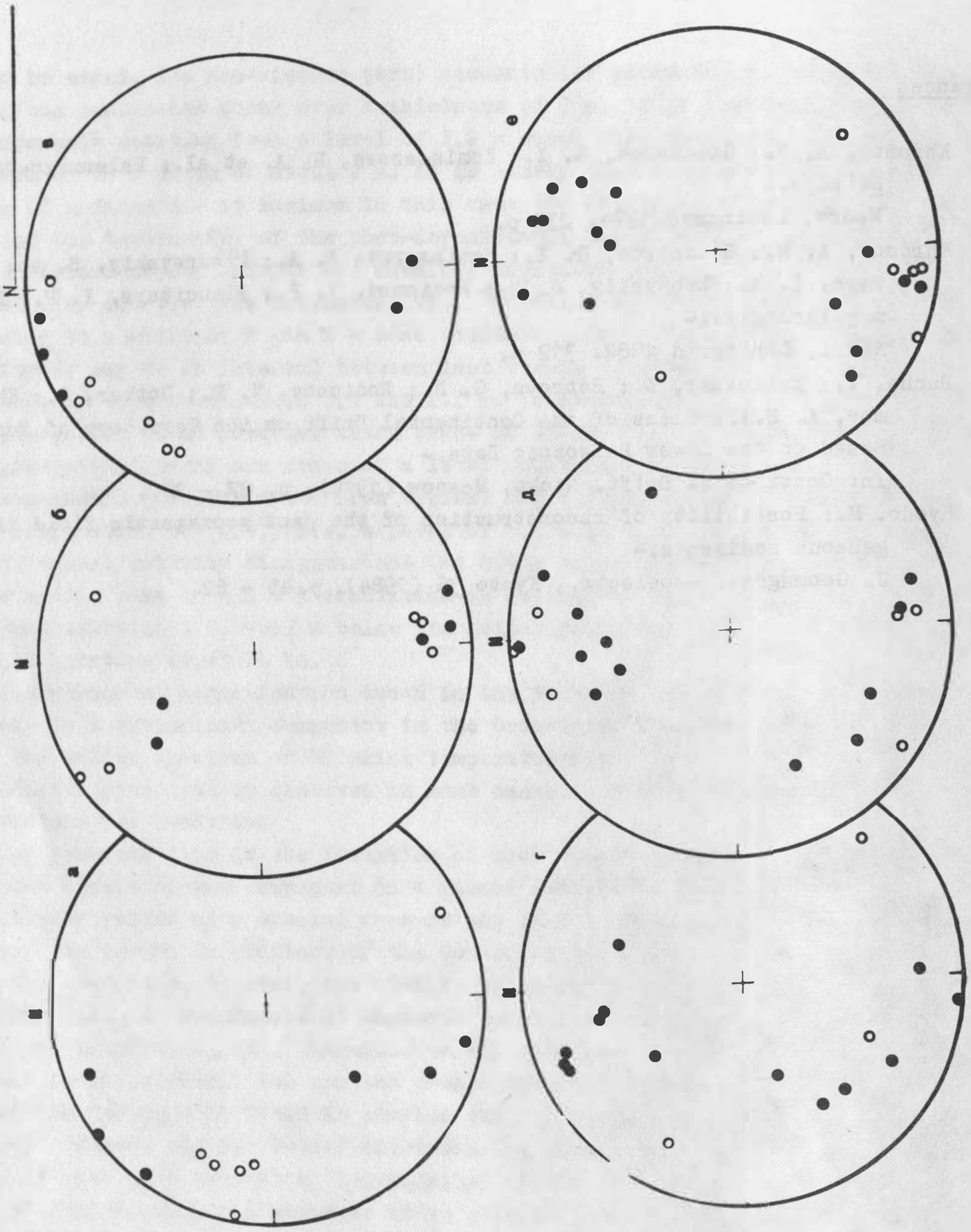

Fig. 2. The NRM-components directions in transitional beds between zones of different polarities in the southern Siberian platform (equidistant projections).

a, b, a - Middle Ordovician, R - N transitions in sections at the villages Chertovskaya and Polovinka;

d, e, f - Upper Cambrian, N - R transitions in the section at the village Khamra;

a, d - components broken within intervals of 8 - 48 kA/m and 150 - 300° C;

b, e - components removed within intervals of 32 - 64 kA/m and 300 - 500° C;

b, f - components left after h = 64 kA/m and T = 500° C.

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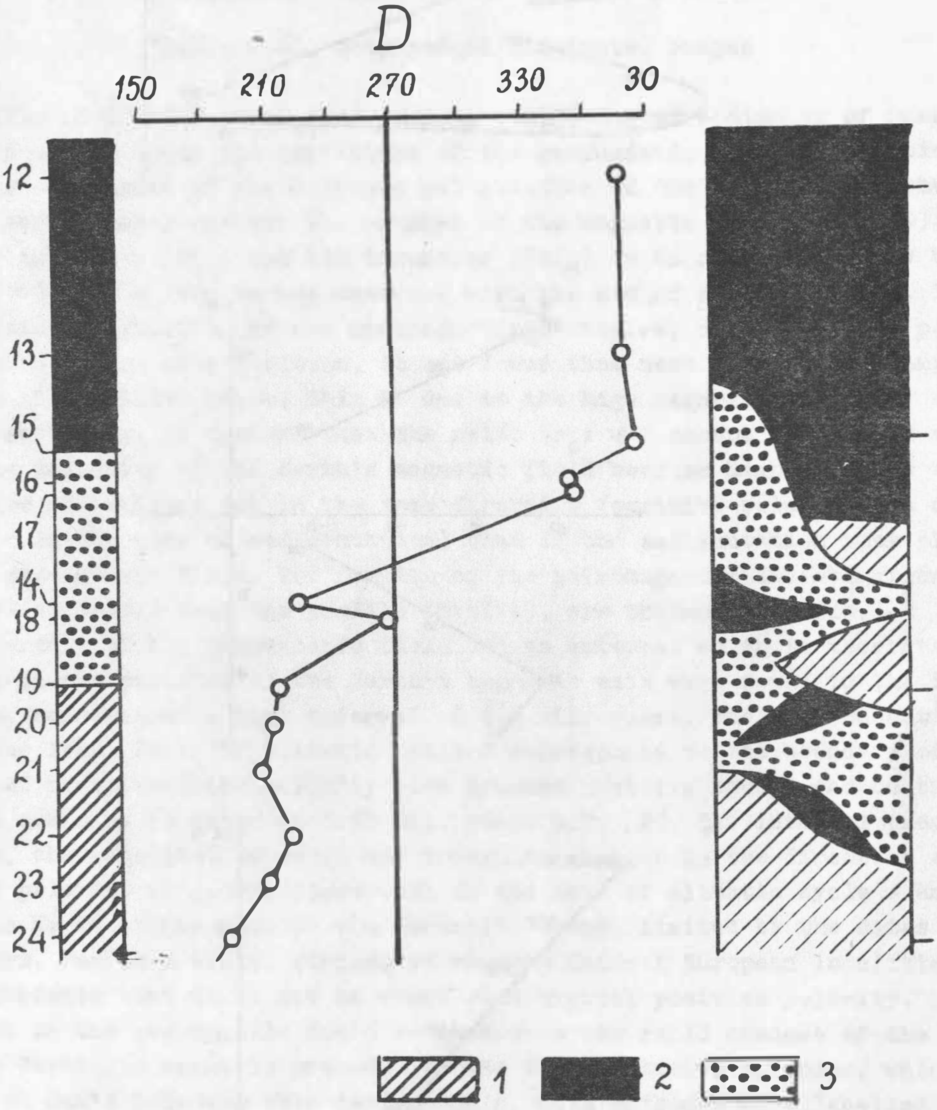

Fig. 3. Paleomagnetic section of the transitional beds of the Verkholensk formation (Upper Cambrian) at the Khamra village (the Lena River). 1 - normal polarity; 2 - reverse polarity; 3 - transitional directions of NRM-components. To the left - subdivision of the section into polarity zones and declination D plot of characteristic magnetization after /3/, to the right - polarity of NRM-components; their stability increase from the left to the right.

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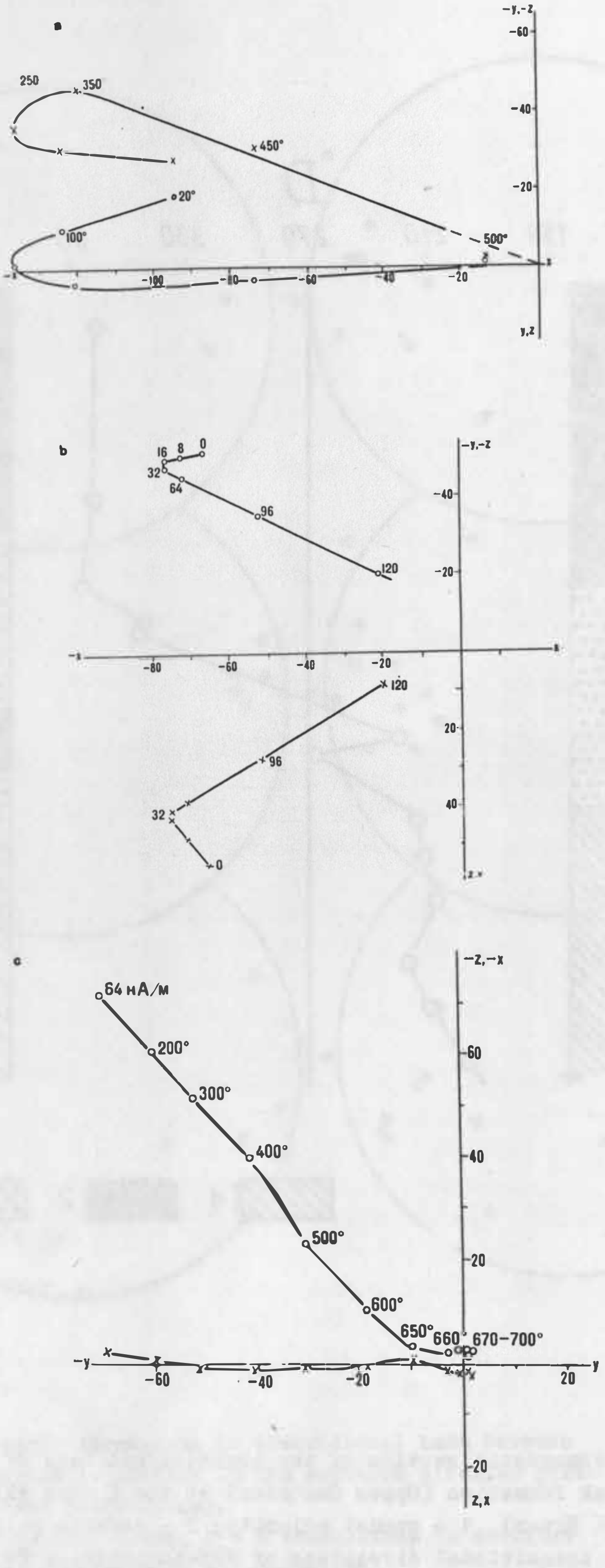

Fig. 1. Zijderveld diagrams plotted from demagnetization of redbeds of the southern Siberian platform. Alternating magnetic field in kA/m, temperature in ^{o}C, projection of $J_n(T,h)$ on X,Y,Z axes in % of J_n prior to demagnetization.

a - sample 9-1, Upper Cambrian, Khamra village;

b - sample 21f-1, Upper Cambrian, Khamra village;

c - sample 3355, Middle Ordovician, the Podkamenneya Tungusska River.

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GEOMAGNETIC FIELD AT THE TIME OF REVERSALS

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The locality of Červený kopec (near Brno), consisting of sediments of Quarternary age [1] was chosen to study the variations of the geomagnetic field at the time of reversals. The measurements of the magnetic polarization of the samples with the aid of a rotational magnetometer enabled the changes of the magnetic declination (D), inclination (I), NRM intensity (Ir_o) and DRM intensity (Ir_{16}) to be determined. The bulk susceptibility ($\varkappa$) of the samples was measured with the aid of KLY 2 -bridge. In measuring the magnetic polarization of the undemagnetized samples, deposited in a position corresponding to the in situ position, it was found that most of the rock samples were magnetized in the positive sense. This is due to the high magnetic viscosity of the investigated sediments. It follows that the ratio $Ir_o : \varkappa$ cannot be used to assess the changes in the intensity of the Earth's magnetic field because higher values of Ir_o are obtained if the two vectors act in the same direction (positive polarization of the geomagnetic field at the time of sedimentation) that if the sedimentation took place under the reversed geomagnetic field. The results of the paleomagnetic investigations of the set of samples collected from the profile involved, are presented in Fig.1.

Three reversals of the geomagnetic field and an interval which is characterized by rapid changes in the position of the Earth's magnetic axis were found in the investigated section, represented a time interval of 0.4 mil. years. The most recent reversal recorded in the loess layer of climatic cycle J corresponds to the boundary of the Matuyama epoch of negative field polarity with Brunhes positive epoch, and on the magnetostratigraphic scale it is dated at 0.73 mil. years B.P. [2]. The interval preceding this boundary, characterized by rapid and irregular changes in the direction of D and by changes of polarity of I, was discovered in the soil of climatic cycle J and in the loess of cycle K; it corresponds to the Jaramillo event, limited by the dates 0.9 and 0.97 mil. years. For this event, studied at various Central European localities [3, 4], it is characteristic that it is not an event with typical positive polarity, but of intensive unrest in the geomagnetic field reflected in the rapid changes of the field's polarity. The Jaramillo event is preceded by two short positive episodes, which were not included on Cox's paleomagnetic dating scale. This episodes were labelled b.J.1 (before Jaramillo) and b.J.2. They can be dated and their time span determined only indirectly on the basis of the average duration of one climatic cycle, which has been determined as 90 thousand years. The younger episode, b.J.1, occurred about 1 mil. years B.P. and other older episode, b.J.2, about 1.1 mil. years B.P. The b.J.2 episode correlates with the positive interval of the polarity of the geomagnetic field, found by Kochegura and Zubakov [5] in the sediments of the Ponto-Caspian region. The occurrence of b.J.1 episode has not been observed yet. The durations of these two episodes are between 5 and 10 thousand years.

The path of the virtual magnetic N paleopole was derived in order to be able to study the changes in the position of the Earth's magnetic axis and the variations of the intensity of the geomagnetic field accompanying this change, and compared with the changes of Ir_{16} and $\varkappa$ (Figs.2-4). To be able to compare the changes in $\varkappa$ and Jr_{16} better, and to be able to distinguish the difference in their behaviour, which would be indicative of changes in the magnetic field, the values of these quantities are given in per cent. The parts of the section consisting of soils in which considerable,

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non uniform, secondary increases of the viscous component of RM occured, and sections with coarse-grained admictures had to be omitted from the comparison. The value 100% was assigned to both quantities in the part of the loess layer of cycle J whose sedimentation occurred at the beginning of Brunhes positive epoch, at the time the field was stabilized (sample No.1). The sections corresponding to the reconstructed path of the paleopole are bounded by dashed lines in the graph.

A gradual movement of the N paleopole from southern geographic latitudes, along meridian 120°E, towards the north is characteristic of the B/M reversal (Fig.2). This path is smooth as far as 20°S. At the Central European localities, this motion is accompanied by a gradual change in D from 180° to 90°. On reaching 20°S, the N paleopole began to move rapidly to the NE as far as 20°N and 120°W. From here the N paleopole moved to 40°N and along meridian 120°E to the N, where its position stabilized. Prior of the reversal (samples 57-43) and after it (samples 8-1) the values of $\varkappa$ and Jr_{16} are roughly in a ratio of 1 : 1. Beginning with sample 40, Ir_{16} is considerably higher than $\varkappa$, in some cases as much as three times. At the time of the change of I from positive polarity to negative, between 20° and 40°N, Ir_{16} decreases to less than 20% of the value before the reversal with $\varkappa$ = 120% ($Ir_{16} : \varkappa = 1:6$). The ratio $Ir_{16} : \varkappa = 1:1$ is again achieved gradually at the time the position of the paleopole stabilized in the northern geographic latitudes. The places where it is assumed that the intensity of the geomagnetic field increased along the path, are marked A, and where it is assumed to have decreased, B.

At the time of the Jaramillo event (Fig.3), very low values of Jr_{16} can be observed relative to the values of $\varkappa$, the ratio $J_{r16} : \varkappa = 1:10$. The considerable decrease of Jr_{16} as compared to $\varkappa$ could be indicative of a weak moment of the geomagnetic field at the time of the sedimentation of the loess of cycle L. This would explain the instability of the geomagnetic field manifested by the rapid changes in the position of the Earth's magnetic axis, documented in Fig.2 by the fluctuation of D and I values.

The movement of the N paleopole at the onest of episode b.J.1 took place along a path similar to that of the B/M reversal, however, the paleopole moved faster (Fig.4). The reverse change from positive to negative values took place along roughly the same path. A sudden change in polarity again occurred around 30°N. In the b.J.1 reversal and Jr_{16} cannot be compared because the type of rock is different in samples 155 to 107. This change is reflected only in the magnetic susceptibility $\varkappa$ (soils, coarsegrained material), but not in the values of Jr_{16}. The low values of the intensity of the geomagnetic field (B) at the time of the change in polarization and the increase in intensity (A) before and after the reversal can only be assumed as a result of the change in Jr_{16}.

Episode b.J.2 represents an incomplete reversal of the geomagnetic field, although a change in the polarity of I from negative to positive values, and vice versa, can be observed at the Central European localities. The path of the paleopole during this episode traced meridian 80°N, and the change from positive values of inclination to negative took place at 20°N. The b.J.2 reversal took place in slope loams whose character corresponds to loesses; this enables the change and the Jr_{16} values to be compared. The onest of the reversal is proceded by a twofold increase of the Jr_{16} values as compared to $\varkappa$ in samples 176-169 (A). The change in the polarity of I is accompanied by extremely low values of Jr_{16} ($Jr_{16} : \varkappa = 1 : 10$). The assumed decrease in the intensity of the geomagnetic field (B) can be observed when the N paleopole was located at 20°N.

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The reverse change of polarity is characterized by as much as a threefold increase in the Jr_{16} values as compared to (A1) in samples 163-155.

Based on the detailed paleomagnetic investigations of Quaternary sediments of the Cervený kopec locality, the manifestations of the geomagnetic field at the time of reversals can be summarized as follows:

1. The path of the virtual magnetic N paleopole during the reversals investigated ran along the Eastern Hemisphere along meridians 120° and 80°E geographic.
2. The reversal of the geomagnetic field is proceeded by an increase in the intensity of the field.
3. During the reversal, an extreme decrease of the intensity of the geomagnetic field can be observed as the virtual magnetic N paleopole moved between 20° and 40°N.
4. The reversible reversal is accompanied by another increase in the intensity of the geomagnetic field; during the irreversible reversal the field intensity stabilized at the pre-reversal value.
5. The rapid changes in the polarity of the geomagnetic field during the Jaramillo event were caused by the very low intensity of the field.

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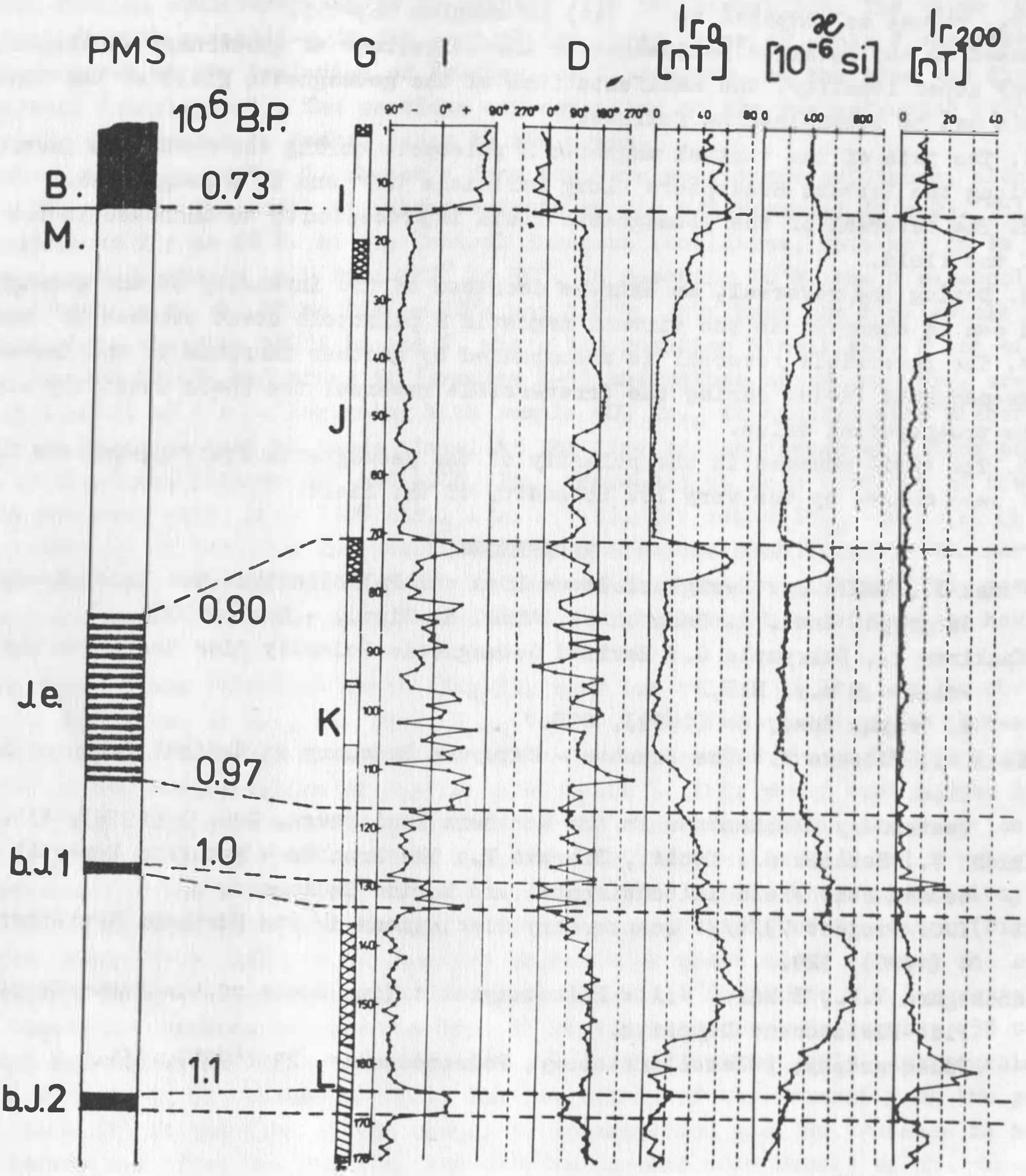

Fig.1. Results of the paleomagnetic investigations at the Červený kopec locality: PMS - paleomagnetic dating scale, G - geological structure of section (I,J,K,L - climatic cycles; white - loess, crossed - soils, dotted - sandy material, hatched - slope loams); 1 - 177 on vertical graph axis - numbers of samples; I - inclination; D - declination; Jr_0 - natural remanent magnetic polarization; - bulk magnetic susceptibility; Jr_{16} - remanent magnetic polarization after cleaning in an A.C. magnetic field of 16 kA/m

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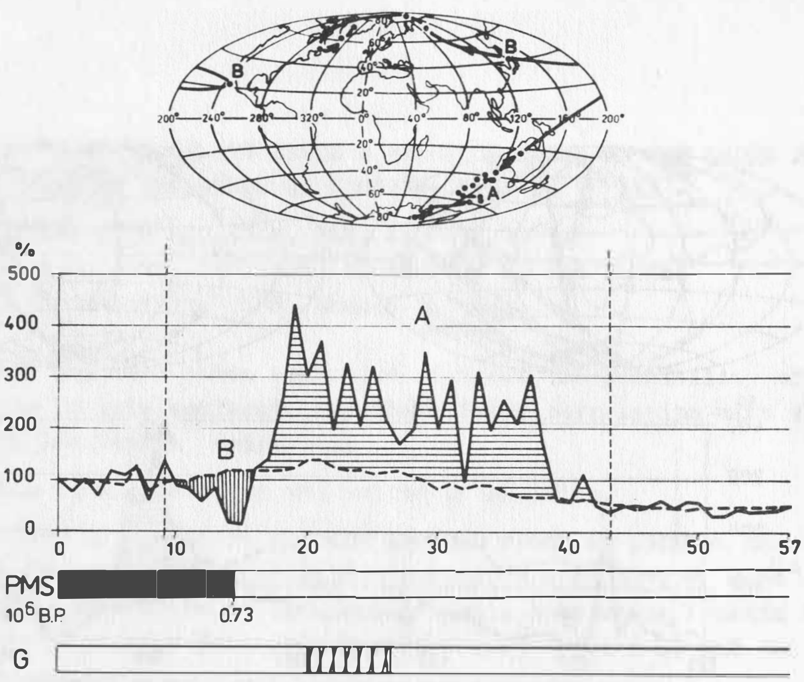

Fig. 2. Variations of the geomagnetic field at the time of the B/M reversal: G - geological structures; PMS - paleomagnetic dating scale; 1 - 57 on horizontal graph axis - numbers of samples; Jr_0 - values (solid curve) and - values (dashed curve) are expressed in % of the quiescent geomagnetic field; A - increased intensity of the geomagnetic field; B - decreased intensity of the geomagnetic field. The vertical dashed lines delineate the section of the illustrated path of the virtual magnetic N paleopole.

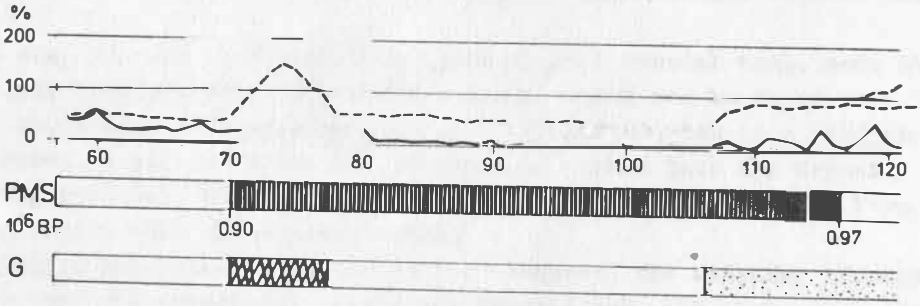

Fig. 3. Variations of the geomagnetic field at the time of the Jaramillo event (for key refer to Fig.2).

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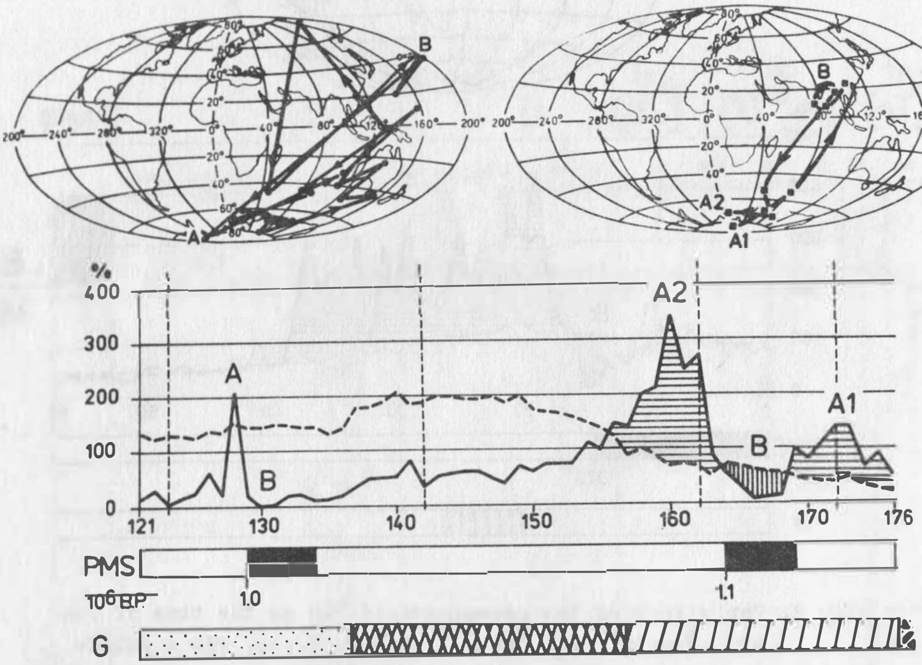

Fig. 4. Variations of the geomagnetic field at the time of episode b.J. 1 and b.J. 2 (for key refer to Fig. 2).

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PALEOSECULAR VARIATION OF THE EARTH'S MAGNETIC FIELD IN THE SHORE PART OF HOLOCENE SEDIMENTS IN KRUKLIN LAKE (NE POLAND)

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The present work has been taken aiming to find out the possibility of PSV-revealing in the shore outcrops of lake sediments and their later correlation with the data obtained for the depth lacustrine sediments.

§ 1. Description of site-section and method of sampling

The profile chosen as a subject for the present study is located on the western side of the Kruklin Lake (8 km NW from Gijitsko-town; $\varphi = 21^\circ 53'$, $\lambda = 54^\circ 03'$ E, 135 m above the sea level). As a result of building a canal, connecting Kruklin Lake with neighboring one in 1854 a water level has been lowered (about 6 m) and the lacustrine sediments have been emerged.

Stratigraphy of deposits of the Kruklin Lake and their lithological characteristics were worked out in Institute of Geography PAN on the basis of the detailed investigations of several profiles. Thickness of deposits in different profiles changes in 3-7 m limits, which is connected mainly with various rates of sedimentation in some parts of the lake. In the lower part of the profile there is a peat layer with the tree-trunk remnants dated by C^{14} method in Hannover Laboratory as 11390 ± 210 BP. Many studies have been done: pollen, granulometric, chemical and other analyses, which have been summarized by dr Stasiak, who constructed a Holocene climatic scale for the site /7,8/. The thickness of the profile under consideration is 2,5 m.

Unfortunately, the lower layers containing peat are not exposed. That's why we have a maximal evaluation of time-interval only. The climatic scale after Stasiak with the corresponding estimation of the duration of each period were applied to the given profile.(fig. 2-1). A lithological column is given too.

The total duration of the studied interval can be estimated as 7000 years and the average rate of sedimentation being equal about 0,5 mm per year.

Sampling was performed by two methods. Some sampling was done with the use of plastic cubic boxes (2x2x2 cm) pushed into the vertical profile wall,which azimuth was fixed by a compass.

Another way of sampling was performed with the help of a special tool, made at Warsaw laboratory. This tool consists of a massive frame, which can be fixed to a vertical profile wall. Three rows of directing cylinders (Ø 2,5 cm, ten in a row) are connected with the frame. A pipe of a smaller diameter is pushed into the deposit through each directing cylinder. Afterwards it is extracted together with the kern. The kern is cut into subsamples with nonmagnetic knife.

The frame azimuth is determined with the help of compass. The sampling through the frame makes safe that the accidental errors are minimalized. The whole collection has more than 550 subsamples from 81 levels of sampling (each level 3 cm thick). A great number of samples (up to 20) was taken from certain levels for checking the statistic parameters.

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§ 2. Paleomagnetic measurements

The collection was devided into two even parts and measured independently at Moscow and Warsaw laboratories.

A set of parameters typical for paleomagnetic investigations was obtained: J_n , D , I , $\varkappa$. Spin - magnetometers (type JR-3 and JR-4) and a kappa-bridge (type KLY-2) were used. While comparing the results it turned out that the data got through two methods of sampling (cubes and cylinders) as well as the data of different laboratories are in full accordance with each other in the limits of the unitype data scatter on each level. The good accordance of the above results allowed to calculate the mean values of paleomagnetic parameters and statistical coefficients for the whole collection. The results are given in Appendix (Table I). Precision - parameter (k) of J_n -directions lies in limits 40 ÷ 400, mean value being 175 and angle of confidence (α_{95}) is changing within $2,4^o - 13^o$, which is satisfying. k -values, calculated for the same level, k_1 , and between the levels, k_2 , (by n = 20 in each case) showed, that $k_1 > k_2$ consistently, though they don't different significantly. It is suggested, that PSV are present in our record.

Mean values of J_n , $\varkappa$, D and I , were used for construction of the logs in fig. 2-1. More detailed analysis of the these logs will be given in § 4. The distinct correlation of J_n and $\varkappa$ drows a special attention. It means that J_n-changes along the profile first of all reflects the ferromagnetic concentration in the sediment. To decrease the influence of concentration the Königsberger's factor was calculated ($Q = J_n/\varkappa$). But in this case the role of numerous fine ferromagnetic grains is not taken into account. Probably the more correct estimation of field intensity change is the relation J_n/J_{ri} . J_{ri} values for two samples from each level was obtained. In fig. 2-2 J_n , $\varkappa$, J_{ri} logs, as well as Q and J_n/J_{ri} curves, drawn through running means of seven points, are shown. It is evident, that there is a close correlation of three first parameters. It means, that J_n -variations are connected mainly with a change of the concentration of ferromagnetic grains both fine and great, the concentration changing considerably with the depth. If we use Q or J_n/J_{ri} values, the influence of concentration is reducing and the curves have more smooth character. If variations of geomagnetic field intensity with period of about 10000 years are real, we can observe of about one half of this oscillation (according to climatic time-scale). From such point of view Q - change and J_n/J_{ri} - change especially are seen as a real field intensity records.

§ 3. Carriers and nature of NRM

Studying of ferromagnetic fraction is necessary to elucidate of NRM nature. Thermodifferential magnetic analysis (DTMA) was used as a first step in this way. It was carried out at Kazan State University after method, suggested by Burov and Jasonov / 3/ . Rate of heating in that experiment is rather high - to reach the $t^o \sim 700^oC$ takes about one hour. The value of a magnetizing constant field is about 2000 Oe . For rocks with a great coercive force such fields are not strictly the saturation fields. Due to a considerable inertion of the device Curie-points are defined within the accuracy of about 50^oC. Method DTMA because of its technical simplicity can be used as a convenient way for preliminary estimation of ferromagne-

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tic fractions and their stability to heating (but not for the accurate determination of the composition). The DTMA-curves were got for a pilot collection (10%) - see fig. 3-1. Their analysis showes that the composition of magnetic fraction of Kruklin Lake sediments is not simple but homogenious. The curves of two types are distributed along the whole profile. Two typical t^o-areas are fixed 300-350°C and 450-600°, what proved the existance of at least two ferromagnetics in the rock. The first one while heating has undergone some changes, possibly destroyed, because the curve of the second heating is smoothed in this t^o-area. The second ferromagnetic (which according to its Curie-point could be magnetite, maghemite, hematite) is also changed while heating, T^o_{cII} being more than T^o_{cI}. To all appearance this process is connected with a new formation of hematite and its T^o_c is seen more distinctly on the curves of the second heating. This process is more remarkable in the subsamples of the second group (fig. 3-1b), where on the curve of the first heating the intensive process of the new formation is reflected (typical "zigzag") and on the curve of the second heating we see two-humped maximum, which could mean the presence of magnetite and hematite simultaniously.

The same phenomenon is confirmed by the curves J_{rs} (t^o of the first and second heatings obtained in Warsaw laboratory for subsampels from five various levels of sampling.

Fig. 3-2 demonstrate 2 pairs of typical curves. On the curves of the first heating is possible to notice the presence of a ferromagnetic with t^o_b in the area 200-400 C°, and the second one with $t^o_b > 500°C$, more probably of a magnetite. The growth of J_{rs} after the first heating is not considerable: J_{rsII}/J_{rsI} changes from 1 up to 1,5. It means, that a new ferromagnetic phase appears in the process of the first heating, being a weak ferromagnetic phase.

Probably it is a hematite, not very noticable against a more strong ferromagnetic. The shape of curves itself is characteristic for a fine grained magnetic. Curves J_{rs} (t^o) of similar type were received in sediment studying of other Northern Poland lakes / 4/ .

The comparison of mean values of same magnetic parameters for Kruklin and nearly Mikolaiskie lakes sediments (table 3-I) confirms the ferromagnetic composition similarity of these lakes sediments.

TABLE 3-I

	J_n (nT)	h/2 (Oe)	H_{cr} (Oe)
Mikolaiskie	15	175	290
Kruklin	12 - 20	160 - 170	240

The presence of fine grained magnetite in cores of North Poland lakes is established by X-Ray method as well.

For some samples so-called saturation parameters method was used (Moscow laboratory). It is following: the change of saturation remanent magnetization (J_{rs}) and remanent coercive force (H_{cr}) after heating, cooling and a new magnetization

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is observed; at each new heating, the temperature was increased by 100°C /6/. Corresponding curves are seen in fig. 3-3. They show the growth as J_{rs} as H_{cr} beginning with 100°C, H_{cr} growing from 20 up to 60 mT. The given change of saturation parameters with heating is characteristic for amorphic hydroxides transformation into hematites.

Thus all magnetomineralogical investigations brought us to the conclusion that the ferromagnetic fraction contains probably amorphic ferric hydroxides, fine grained magnetite and hematite.

As the magnetic methods allow to define the composition of a ferromagnetic fraction only, it is pertinent to use some nonmagnetic method of diagnostics of Fe-minerals as a whole; in the given case Mössbauer spectroscopy analysis was made by T.S. Gendler /10/ in Moscow Lab. It is important to know the composition of a sediment as a whole, because the safety of natural remanent magnetization depends considerably on paragenesis of minerals in rock. Within the rock life new ferromagnetics can appear due to the changes of paramagnetic material especially silicates contained in the sediment in big quantities. The total part of ferromagnetic minerals in the studied sediments is very little what excluded the possibility of magnetic separation, therefore the analysis of the ferromagnetic failed to be done. It was fullfilled on a samples of the sediment under consideration. According to types and parameters of γ -resonant spectra the main minerals are silicates (montmorillonite) and amorphic ferric hydroxides covering fine clay grains with thin layers. Typical spectrum of studied sediment are seen in fig. 3-4. They consist of two nonresolved doublets with parameters corresponding Fe^{3+} and Fe^{2+} in silicate octaedric environment latice. The presence of Fe^{2+} along the whole section and constant relation Fe^{2+}/Fe^{3+} calculated according to spectra area says about a partially reducing conditions in the sediment consolidation. This supposed a relative safety of primary ferromagnetic minerals. After heating up to 400°C the spectra are changing: broadening of central doublet and disappearence of Fe^{2+} doublet occur. All this respond to the process of intensive silicate oxydation whole heating. As a rule under such oxidation of montmorillonite losening of Fe^{3+} ions and Fe -oxides formation, mainly hematite of different ordering degree, take place. Dehydration causes formation of secondary hematite as well / 7/. Thus, the peculiarities seen on curves $dJ_s/dt\ (t^0)$ and $J_{rs}\ (t^0)$ of second heating as well on saturation parameters curves (typical growth of J_{rs} and H_{cr}) correspond to the changes in paramagnetics but not in primary ferromagnetics.

The above said confirmed that the main NRM-carrier in fine grained magnetite (input of Fe-hydroxides and hematite is very little by contrast to magnetite) which has not suffered any noticable changes since sedimentation period. Using another words NRM has the orientational (detrital) nature (DRM).

To confirm this hypothesis another experiment was performed (Moscow Lab.). Fig. 3-5 demonstrates typical $J_n(\breve{h})$ -curves in comparison with $J_{ri}(\breve{h})$ -curves before cleaning (a), after cleaning up to $t^o = 100^oC$ (b) and up to $t^o = 200^oC$ (c). In the first case curve $J_n(\breve{h})$ lies higher than $J_{ri}(\breve{h})$ after demagnetization by $\tilde{h} = 30$ mT only. During thermocleaning a viscous remanent magnetization is removing, and relation between J_n and J_{ri} becomes more typical

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for DRM: $J_n < J_{ri}$ in 4-6 times but more steady in alternating field. In this experiment a direction of natural remanent magnetization dont change considerably (within the standart error). It shows that has only one component.

This feature of J_n is seen more distinctly in Zijderveld-diagrams on temperatures (Warsaw Lab.), which demonstrate (fig. 3-6) that the vector change occurs up to 100°C and then the direction of J_n becomes stabilized. It is connected with removing of viscous remanent magnetization.

Mass thermocleaning (100^o and 200^oC) of sub-samples (2 out of level) demonstrated that the direction change is neglectable. Therefore J_{rv} is law and is easily removed by heating or alternating field. Postsedimentational magnetization (PDRM) if exists has a not remarkable difference in time of formation. Thus none of disturbed magnetization (VRM, CRM and PDRM) is important.

All described results of study of NRM confirm that gyttia sediments of Kruklin Lake along sampled profile are fully useful for the measuring magnetic declination and inclination and deducing the PSV variations on this base.

§ 4. Spectral analysis of PSV for magnetic declination and inclination records

The periodical character of declination and inclination records along the studied profile of lacustrine sediments is demonstrated in fig. 2-1.

However it is difficult to isolate by eye the periods of D and I variation traced in the function of time, as the rates of sedimentation are different in the individual sub-periods of Holocene. To change the depth to the real time-scale is not simple and usually is carried out with assumptions about rates of sedimentation. In our case we have not absolute data, that is why time-scale can be adopted on a base of a climatic scale only. If the sedimentation rate could be uniform its value can be adopted being equal about 0,5 mm/year (inverse value) more suitable by time-series analysis $w \approx 50$ year/level). But the main part of sampled profile was deposited in Subboreal and Atlantic periods, when mean sedimentation rate was higher, and $w = 35$ year/level. If we use for analysis Atlantic-period only, $w = 33{,}5$ year/level. All versions were used in further calculations.

The spectral analysis was fulfiled using the MEM-spectrum after Burg /2/. The MEM spectrum of a stationary random uniformly sampled process is found as that spectrum that results from maximizing the entropy of that process. We use a program worked out by S.Fillipov.

Three appreciable maxima were revealed in power spectra of declination curves (in arbitrary units) computed separately. Results (for 3 version of sedimentation rate value) are demonstrated in Table 4-I. Only steady maxima of power spectra repeating for different filter lengths were taken into consideration and put into table.

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TABLE 4-1

Results of spectral analysis (MEM)

Periods analysed \ Harmonics in arbitrary units	12	30-33	69-75
Whole section = 50 year/level	600 year	1500-1660 year	3500-3700 year
Subboreal + Atlantic = 35 year/level	420 year	1050-1150 year	2500-2650 year
Atlantic = 33,5 year/level	400 year	1000-1100 year	2300 year

In our opinion most reliable results are these, computed for Atlantic and Subboreal periods. All harmonic obtained: 420, 1050-1150 and 2500-2650 years, correspond to these, well known due to world data, archaeo- and paleomagnetic

Conclusions

Paleomagnetic results from Holocene lake sediments are available for many parts of Europe ranging from Greece, northwards through Poland, Finland and westwards through Switzerland, France and England. Spectral analysis of this set of paleomagnetic data from rapidly deposited lacustrine lake sediments (Barton, 1982) places the principal periods of D and I variations recorded in them in the range between 10^2 and 10^4 years.

Our results for Kruklin Lake sediments lie in this range. The direct comparision course of D and I records as well as other parameters (mean susceptibility and intensity of NRM) along the studied profile of Kruklin Lake sediments with the same parameters for any core of bottom sediments from any lake from North Poland /4/ , is impossible as in the individual cores the different rates of sedimentation were noted and the different time spans were studied, so it is difficult to find the coincided segments particullary without absolute dating in our studied section. On the other hand it is worth while to say that the spectral analysis of inclination records from cores from Mikolajskie Lake /5/ and later study of short-periods variations noted in north polish lakes /9/ confirm the periods determined in sediments from Kruklin Lake.

Thus sections of shore sediments give the results which correspond satisfactorily to the bottom sediments.

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APPENDIX
TABLE I

RESULTS OF NRM MEASUREMENTS FOR INDIVIDUAL SAMPLING LEVELS OF KRUKLIN LAKE SEDIMENTS

Nr of level	Number of samples	Intensity of NRM	Mean declination	Mean inclination	Statistical coefficients		Mean suscept. ($\times 10^{-6}$ SI)	Königsberger coefficient
1	2	3	4	5	6	7	8	9
1	5	4.8	8°	70°	68	8°	14.5	0.35
2	5	7.4	-12	80	176	5		
3	8	6.7	0	79	132	4	16.4	0.41
4	6	5.3	8	79	177	4		
5	7	5.8	-2	76	105	5	17.0	0.34
6	5	4.6	-7	82	138	5		
7	7	7.6	0	74	105	5	22.5	0.32
8	6	11.6	-6	80	427	3		
9	8	7.7	2	73	103	5	27.8	0.30
10	4	5.3	22	77	370	4		
11	7	5.3	-10	71	75	6	19.1	0.27
12	7	9.3	+1	71	211	4		
13	8	9.8	-15	65	98	5	27.3	0.35
14	8	9.5	-11	73	166	4		
15	7	8.4	-15	64	72	6	26.5	0.29
16	6	10.5	-2	78	237	4		
17	10	9.3	-6	60	76	5	27.2	0.35
18	8	13.1	-9	67	203	4		
19	9	8.9	-7	68	98	5	25.4	0.34
20	3	9.0	-8	61	39	13		
21	8	8.9	-10	65	101	5	25.2	0.35
22	6	9.3	9	73	85	6		
23	6	9.5	-11	67	55	8	30.0	0.33
24	6	9.9	-4	65	118	5		
25	7	7.2	-12	62	97	5	25.3	0.29
26	6	9.0	-6	67	98	6		
27	5	7.7	-4	65	90	7	24.7	0.33
28	6	10.6	-7	71	138	5		
29	20	11.0	-10	64	175	2	47.2	0.28
30	5	8.5	-11	68	66	8		
31	4	10.9	-10	69	336	4	40.2	0.28
32	6	10.4	14	64	122	5		
33	6	13.7	-16°	61°	41	9°	42.9	0.34
34	6	12.5	4	65	114	5		
35	5	14.0	-2	64	70	8	43.7	0.34
36	6	10.0	5	70	375	3		
37	7	7.9	-11	68	71	6	21.8	0.38

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1	2	3	4	5	6	7	8	9
38	6	8.3	8	71	237	4		
39	7	8.0	10	71	110	5	20.6	0.41
40	4	9.0	9	75	307	4		
41	4	11.0	12	75	328	4	29.8	0.42
42	8	5.4	4	67	69	6		
43	7	8.3	17	70	408	3	17.7	0.51
44	6	6.7	4	70	123	5		
45	5	7.7	6	71	183	5	21.5	0.35
46	5	7.5	-1	71	144	5		
47	8	10.8	12	68	173	4	38.0	0.29
48	7	13.2	4	69	148	4		
49	7	14.4	9	71	338	3	47.5	0.41
50	5	15.2	-4	71	246	4		
51	5	19.7	-5	72	87	5	51.1	0.41
52	6	14.9	2	66	105	6		
53	6	18.7	-5	62	63	7	52.5	0.39
54	5	7.1	0	61	149	7		
55	5	6.0	-18	65	77	7	18.8	0.35
56	5	6.1	-2	66	268	4		
57	5	5.2	-11	62	59	8	16.4	0.36
58	8	6.7	-11	71	321	5		
59	12	6.1	-2	71	83	5	21.8	0.36
60	6	6.6	-15	66	244	4		
61	6	9.0	6	63	51	8	18.5	0.56
62	6	16.7	-10	71	352	3		
63	7	18.5	12	64	240	3	55.0	0.34
64	6	20.2	-10	62	89	6		
65	7	11.5	13	65	182	4	44.3	0.27
66	8	5.9	-10	64	113	5		
67	8	4.8	-4	64	62	7	18.5	0.24
68	5	5.4	-7	65	113	6		
69	7	7.0	-2	70	64	6	24.3	0.29
70	5	24.8	-6	70	84	7		
71	3	2.8	-12	64	385	4	16.0	0.16
72	4	1.6	-4	74	64	9		
73	6	7.9	-7	72	156	5	28.5	0.29
74	2	18.2	-8	72	–	–	–	–
75	7	5.3	3	68	75	6	28.5	0.23
76	5	2.3	-12	66	42	10		
77	5	1.5	2	66	34	11	18.0	0.09
78	4	1.0	-3	63	–	–	–	–
79	6	1.2	-9	63	21	12	20.2	0.06
80	3	1.6	21	72	89	9		
81	3	6.5	8	71	103	8	47.7	0.14

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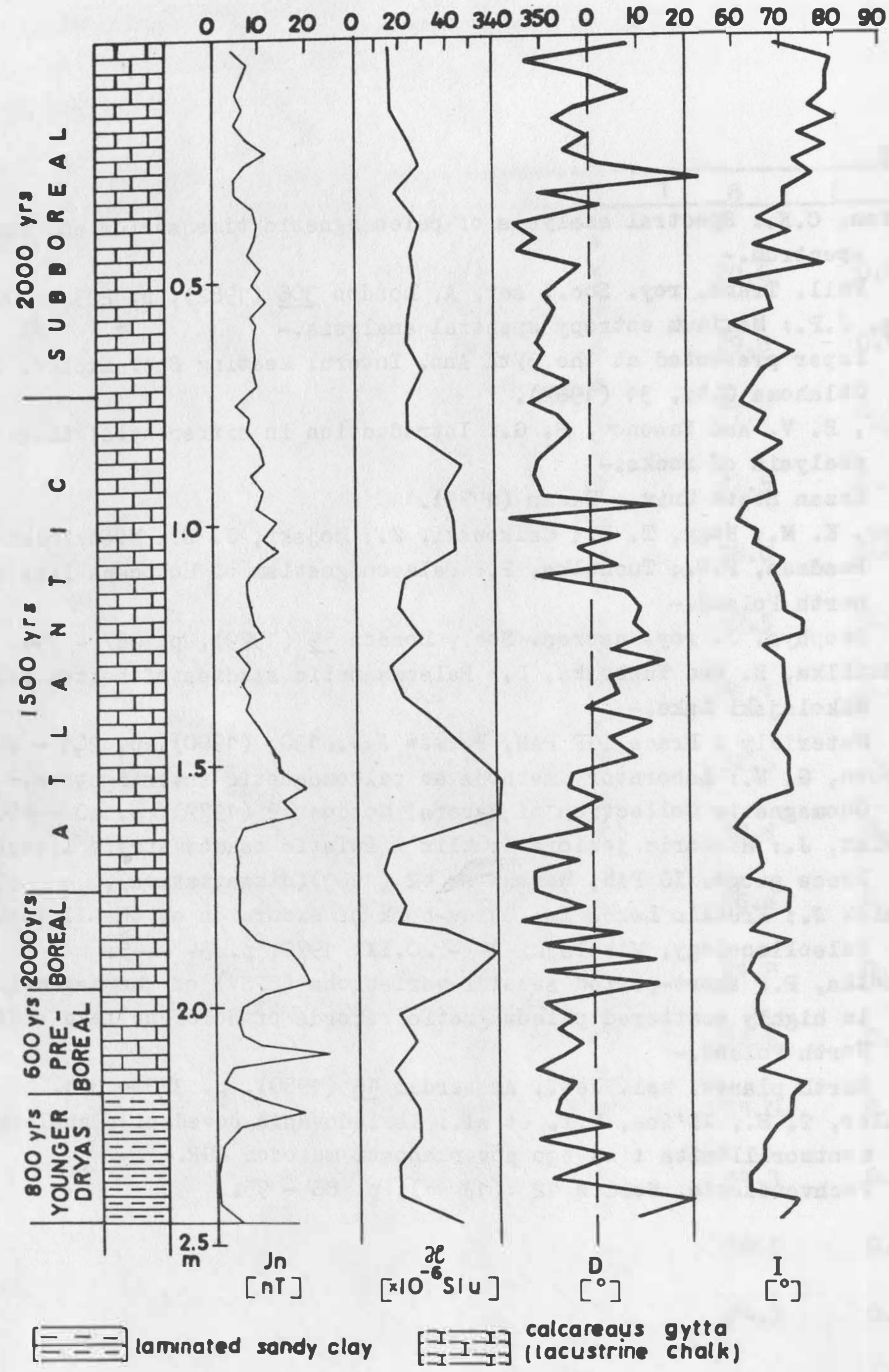

Fig. 2-1. The results of paleomagnetic studies of Kruklin Lake sediments. Left columns - geological description of the sampled profile with subdivision of Holocene into sub-periods.

J_n - intensity of NRM

æ - mean magnetic susceptibility

D - magnetic declination

I - magnetic inclination

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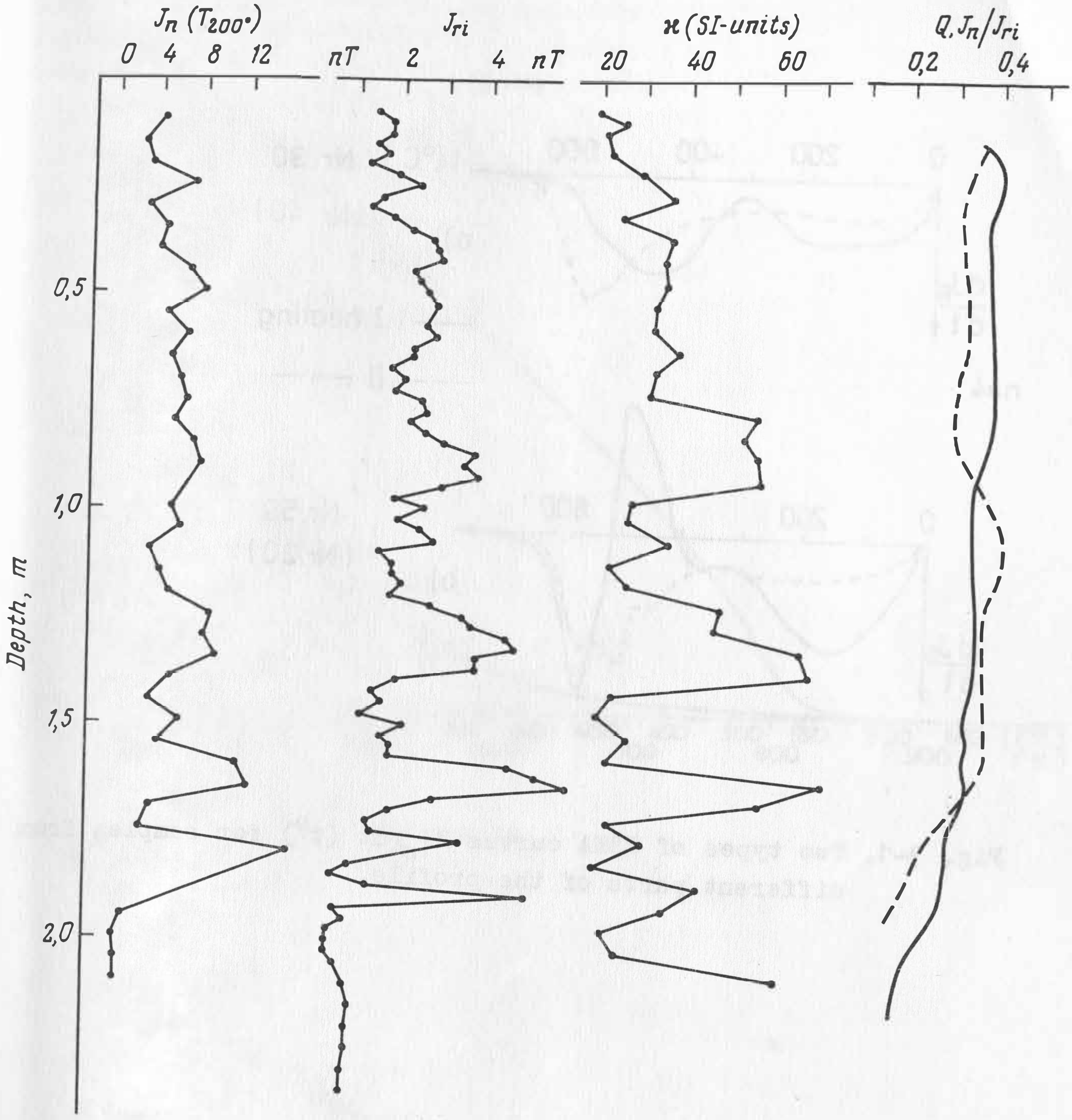

Fig. 2-2. Comparison of the variation curves of J_n, J_{ri}, æ, Q (dashed line) and J_n/J_{ri} (solid line) of the Kruklin Lake profile.

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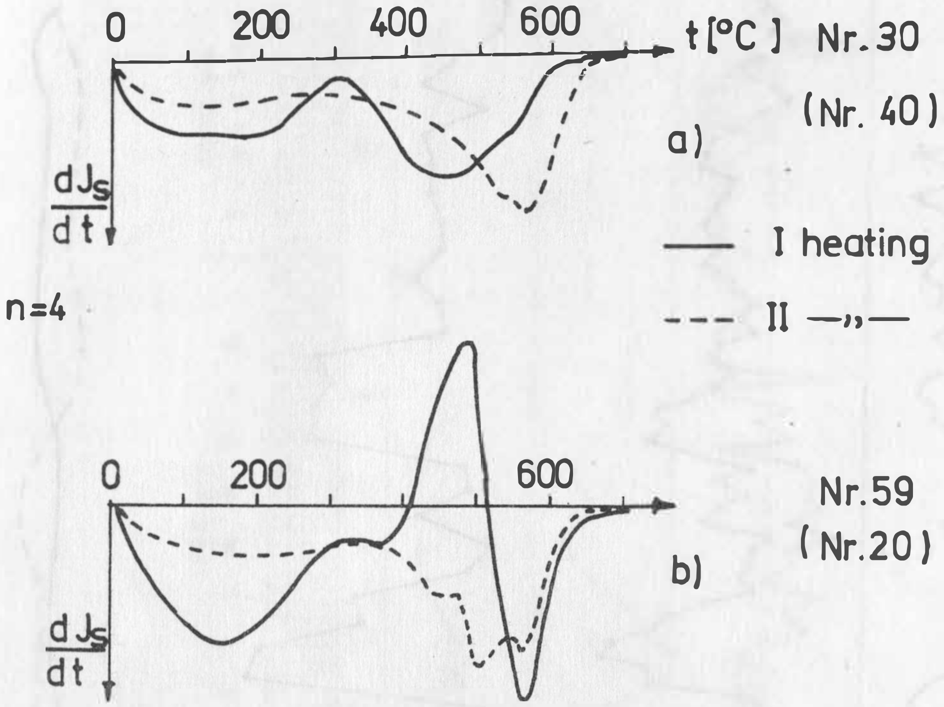

Fig. 3-1. Two types of TDMA curves dJ_s/dt (t^o) for samples from different parts of the profile.

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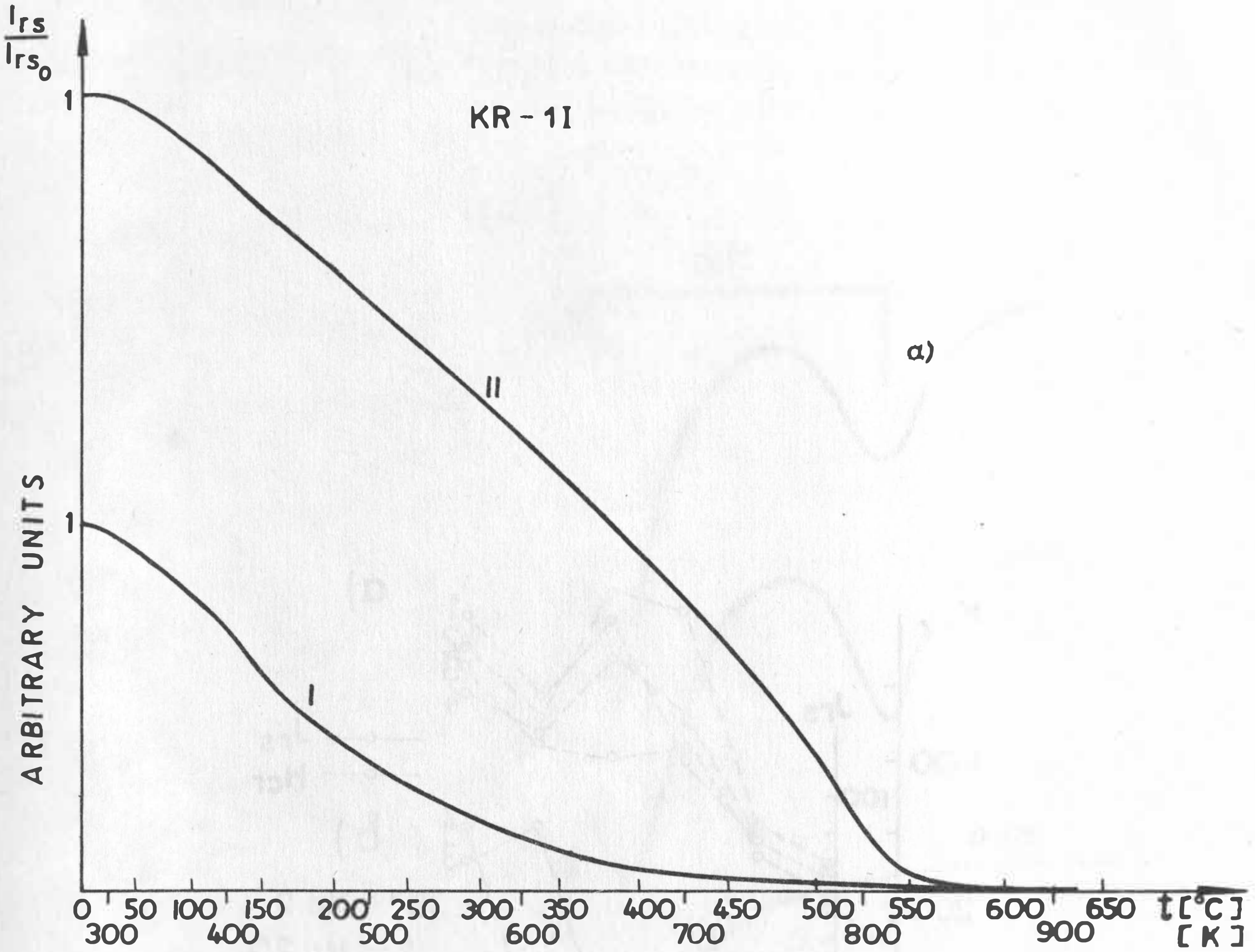

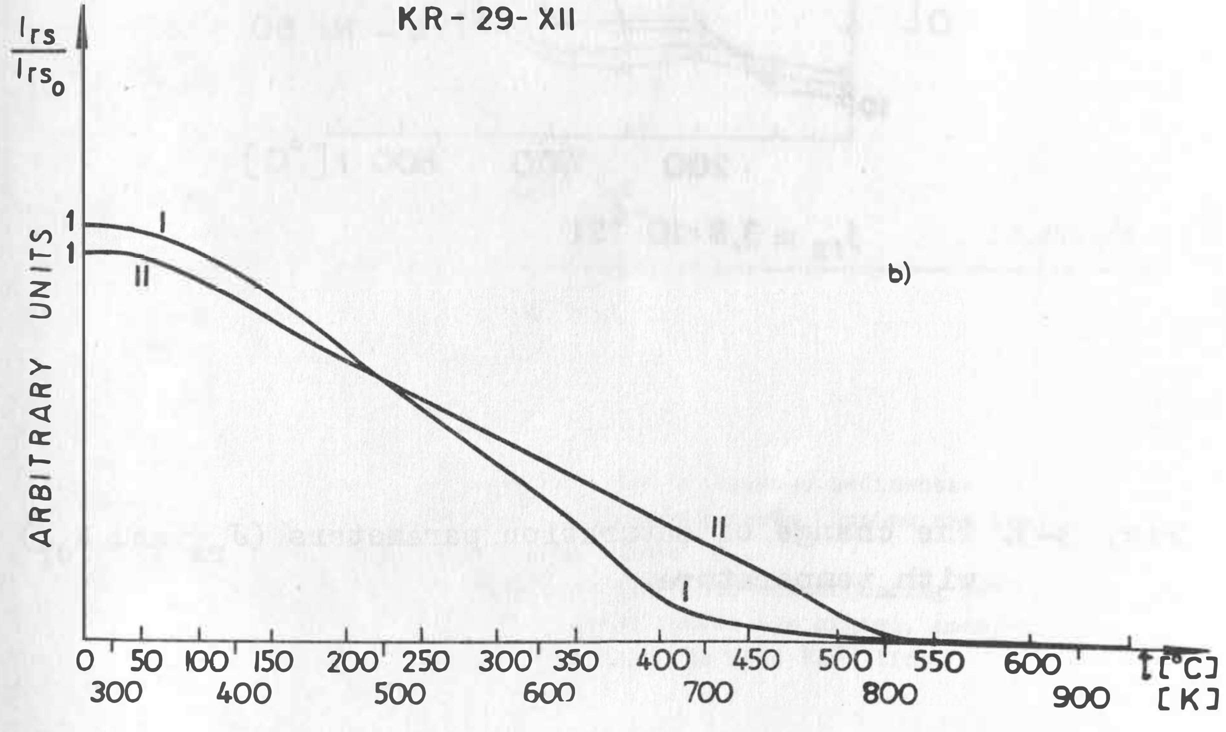

Fig. 3-2. The dependence of the remanent saturation magnetization on temperature during the first and second heating (samples KR-1I and KR-29-XII).

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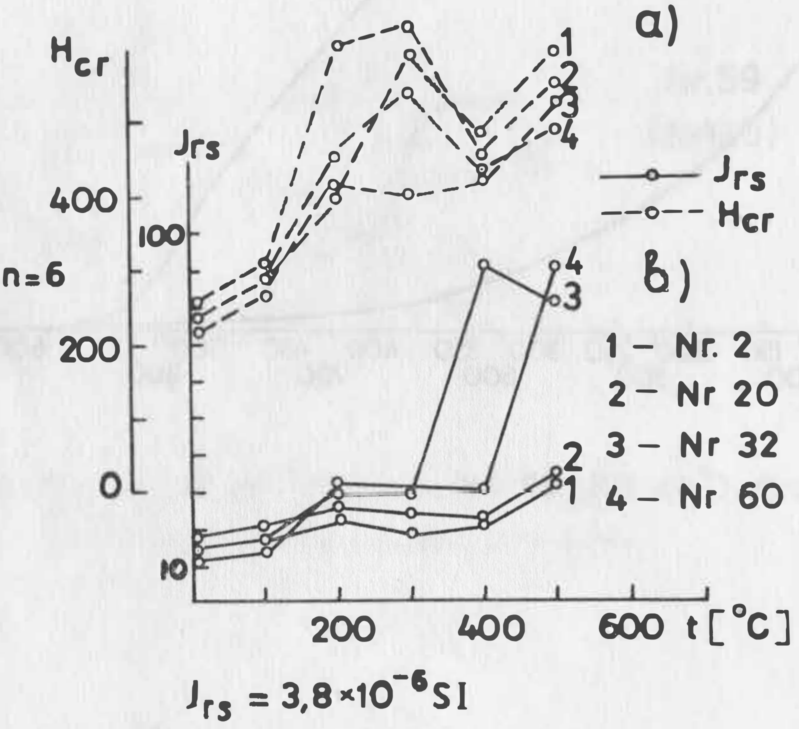

Fig. 3-3. The change of saturation parameters (J_{rs} and H_{cr}) with temperature.

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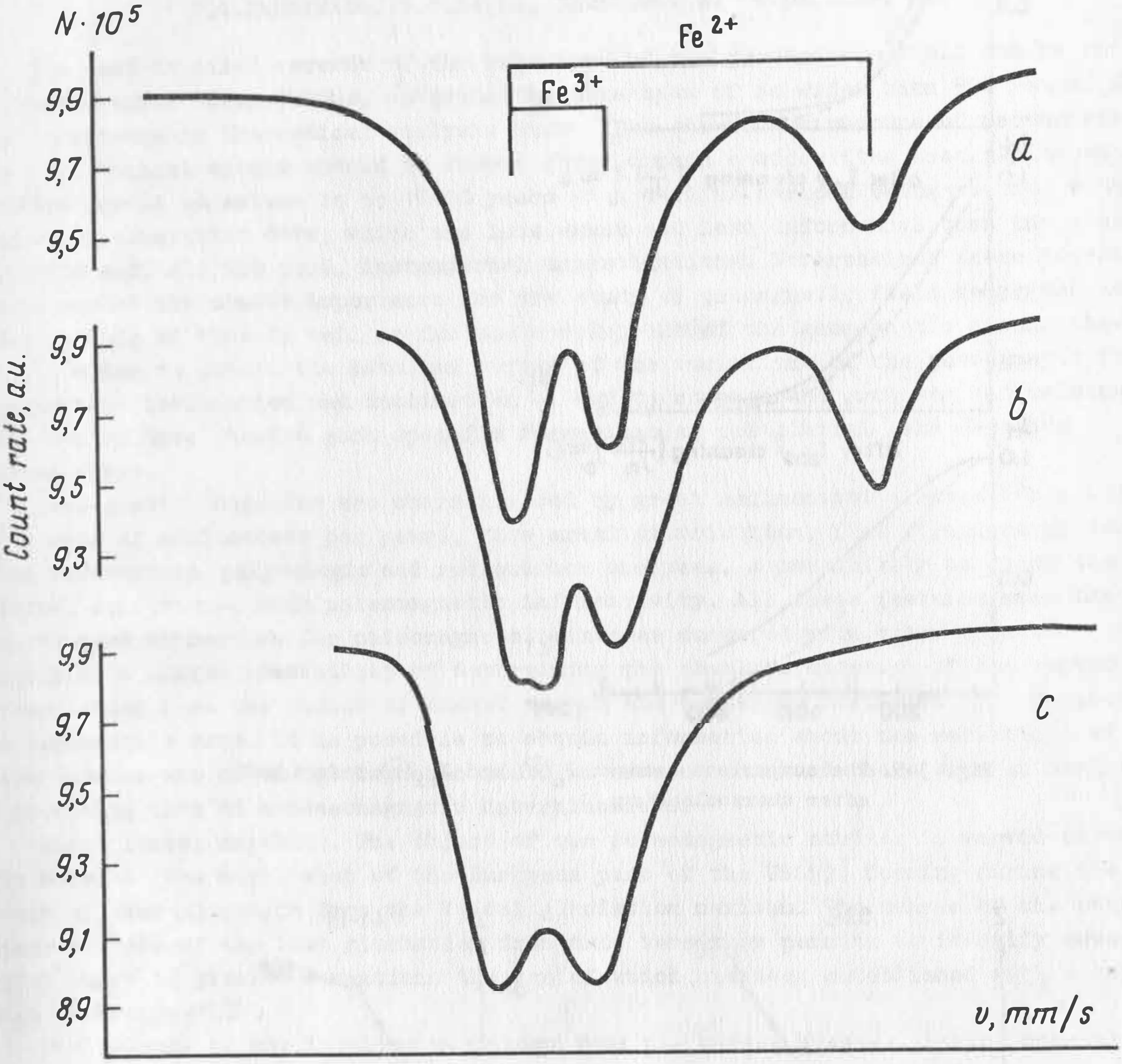

Fig. 3-4. Typical γ-resonant spectra of studied sediments:
a,b - subsamples from different parts (bottom and top)
c - after heating up to 400° C.
Above the spectrum line positions corresponding Fe^{2+} and Fe^{3+} lines in montmorillonite are signed. Amorphic ferric hydroxide lines coincide with Fe^{3+} line position.

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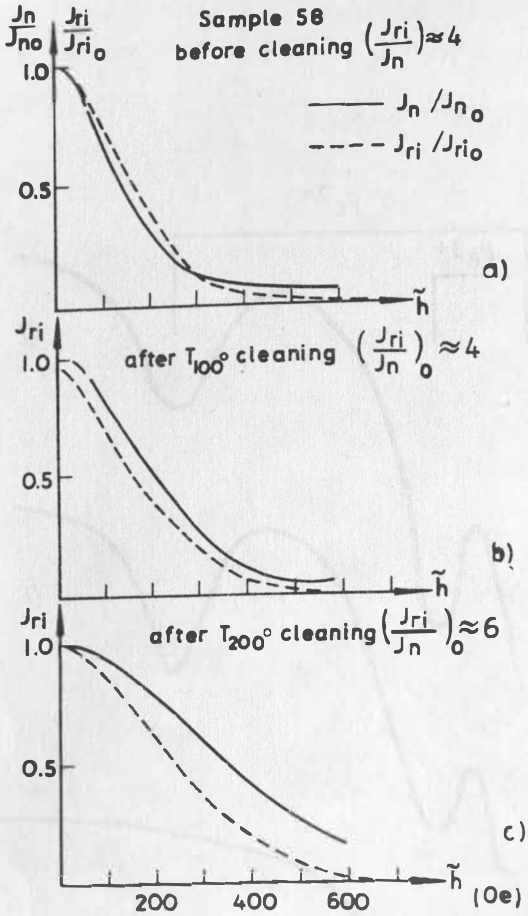

Fig. 3-5. The comparison between $J_n(\tilde{h})$ and $J_{ri}(\tilde{h})$ before and after thermocleaning.

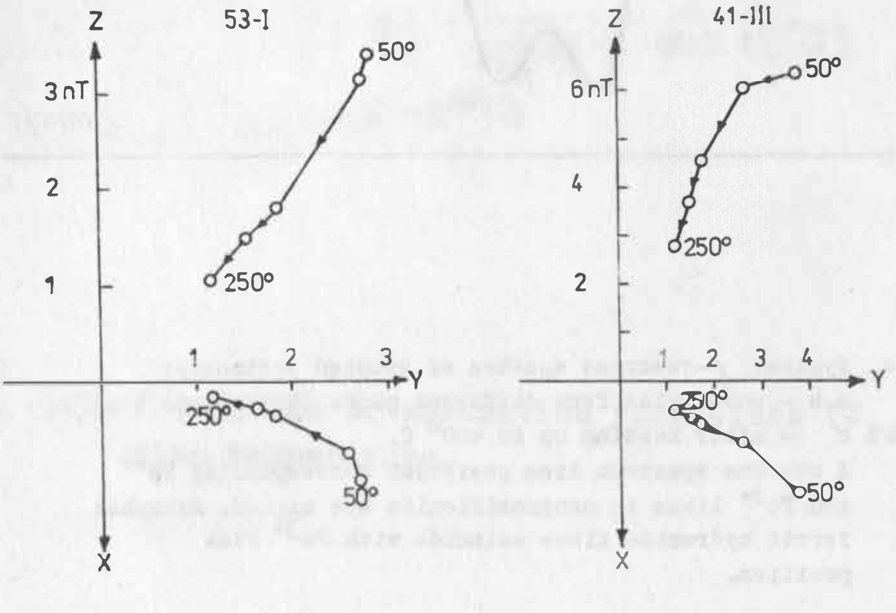

Fig. 3-6. The example of Zijderveld diagram for two samples heated to 250°C.

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SECULAR VARIATIONS OF THE GEOMAGNETIC FIELD FROM PALEOMAGNETIC STUDIES OF THE KARELIAN VARVED CLAYS

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The most detailed records of the behaviour of the geomagnetic field can be obtained by instrumental observations, covering the time span of no wider than 500 years. However the experience in theoretical analysis shows that the fine structure of geomagnetic field for more ancient epochs should be investigated within a wider time span. Archaeomagnetic studies permit to extend it to 10000 years with earlier periods being studied with the use of paleomagnetic data, which are less exact and less informative than the archaeomagnetic and, all the more, instrumental investigations. Nevertheless these investigations are of the utmost importance for the study of geomagnetic field behaviour during long periods of time as well as for the development of the geomagnetic dynamo theory.

In order to obtain the detailed curves of the variations of the geomagnetic field component - declination and inclination -, and to compare the archaeo- and paleomagnetic data we have studied such specific formations as postglacial lake deposits - the varved clays.

Lake-glacial deposits are characterized by great sedimentation rates (from units to dozens of millimeters per year), wide areal distribution, fine stratigraphy derived from varvometric palynologic and radiocarbon analyses, a possibility to study them in natural conditions, high paleomagnetic informativity. All these features make these deposits more attractive for paleomagnetologists as compared with other objects. Noteworthy is a unique possibility of determining the absolute duration of the varved clays accumulation from the number of annual varves and comparing different objects according to varvometric data. It is possible to obtain information about the variations of angular components of the geomagnetic field in several thousand years with an accuracy approaching that of archaeomagnetic determinations.

Lake glacial deposits. The object of our paleomagnetic studies is varved clays of the Karelia (the north-west of the European part of the USSR), forming during the retreat of glacial margin from the Valdai glaciation maximum. The scheme of the stage-by-stage retreat of the last glaciation from this territory permits to identify several marginal zones of glacial formations the age of which has been established with a rather high accuracy. /1,2/.

The release of the Karelian territory from the active glacial blanket took place 17000-9500 years ago progressing from south-east to north-west. In this direction one can trace successively the adjacent areas of sedimentation related to different zones of deglaciation, and coordinate them in a single continuous chain. Fig.1 shows the locations of objects studied relative to the margin zones of glacial formations which can be used as geochronological reference. Since the cross-sections show moraine strata underlying varved clays - the time of the onset of the varved clay formation can be established for each of them. For example, the retreat of glacier margin from the terminal moraines at the Neva stage is estimated to occur approximately 12250 years ago. At this very time the varved clays formation in the cross-section 3 located near this zone, might begin to form.

The stages of Salpausselkä I, II, III have been studied in most details, their ages being estimated in Finland from the results of the varvometric, radiocarbon and sporopollen analyses. The retreat of the glacier margin in vicinity of Salpausselka II range is estimated to occur 102000-103000 years ago. The analysis of the geological evidence at

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hand as well as the results of the varvometric and sporopollen studies (the latter have been carried out in the Karelian Branch of the Geological Institute of **Academy of Sciences** of the USSR) show this age to mark the end of the varved clay sedimentation on the cross-section I, so we can tie it chronologically to the time scale /3,4/.

Investigation technique. The number of winter and summer varves has been determined for each section after deep clearing. Then a continuous sampling was made, the samples being oriented relative to magnetic meridian. Every 5 cm through the whole strata of sediments 3 cubic samples were cut out 5 cm long. At clearing parallel with principle one pilot sampling of doublicates spaced vertically at 0.25-0.5 m has been made /5/.

We took more than 2000 samples of varved clays from six sections, located in different deglaciation zones and providing a most completely coverage of the time span. Laboratory studies permit to find that fine-grained magnetite is the main ferromagnetic component-carrier of the remanent magnetization.

Measurements of the collection were made with the help of astatic magnetometer, the first measurements showing good consistency of the results for the specimens of the same age. Nevertheless, all the samples were subject to temperature cleaning at $t=150^{\circ}C$; the change of the angle component did not exceed 10°, being generally smaller than 5°. All results were plotted using the same time scale. At sedimentation rates > 0.3 cm/year averaging was made over 30 year interval, while for the rates < 0.3 cm/year the averaging intervals were 50-year. The results are shown in Fig.2; the declination are related to the geographic meridian. Each point in Fig.1 corresponds to the mean value for 30 to 50 years which is the results of an averaging over 6 to 15 samples, depending on the sedimentation rates. In most cases α_{95} ranges from 1° to 3°, and data-point density parameter K exceeds 500.

Secular variations. Comparison of the paleomagnetic results with account of the age of each section show a good agreement between the declination and inclination curves. The section numbers in Fig.2 are the same as in Fig.1. We have no exact age correspondence for each object with the time scale; geochronological researches similar to those in Sweden /6/ or Finland /4/ have failed. That is why for a more exact stratification of sediments we have used the results of our paleomagnetic studies, together with age data available. On the one hand, that has permitted us to refine the formation time for each section, and to make a more exact correlation between them, on the other hand we have obtained the proof of the geophysical nature of the declination-inclination variations. A good agreement of the results for the sections related to different deglaciation zones with different sedimentation rates (from 0.15 to 1.0 and more cm/year) allows to state that the curves obtained reflect the changes in the geomagnetic field components for almost 6000 years. The amplitude of the declination variations reaches 70°, while that for inclination is nearly half as large. In general declination changes asymmetrically about the geographic meridian with dominating westerly displacement. The mean inclination value is equal 66°. Some data on inclination indicate its possible systematic decrease by a value no larger than 10°. Noteworthy is a great amplitude of the declination change about 12000 years ago. The declination direction changed sharply (by 70°) from the eastern to western one for a time span of about 300 years, the change in inclination being insignificant.

The drift of the virtual geomagnetic pole for 6000 years is characterized by a complicated loop like trajectory; it was both counted clockwise and anticlockwise, the first is dominating. During its migration the pole drifted no lower than 55°N.

There are no results for time about 12600 years ago. On the cross-section 4 the clays

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are strongly deformed at this level due to landsliding. Here the duration of the interruption is estimated as maximum two - three hundred years, and there is no reason to believe that the behaviour of the geomagnetic field could change drastically for such a short period of time.

The analysis of the declination-inclination variations with the account of the results of the earlier archaeomagnetic studies /7/ allowed us to draw preliminary conclusions about the existence of a substantial effect of a nondipole source of the geomagnetic field. Moreover, this effect grows when passing from the older sediments to the younger ones. The discussion of the problems, related to the morphology of secular variations, their spectra, nondipole components separation, etc. is beyound the scope of this paper.

In conclusion it should be noted that the detailed information obtained about the declination-inclination variations in the time span of 10000-16000 years and based on it detailed scale of the angular component variations constructed on this may be successively used and is being used now to solve the problems of geochronology and stratigraphy of the late glacial sediments on the territory of the North-West of the European part of the USSR.

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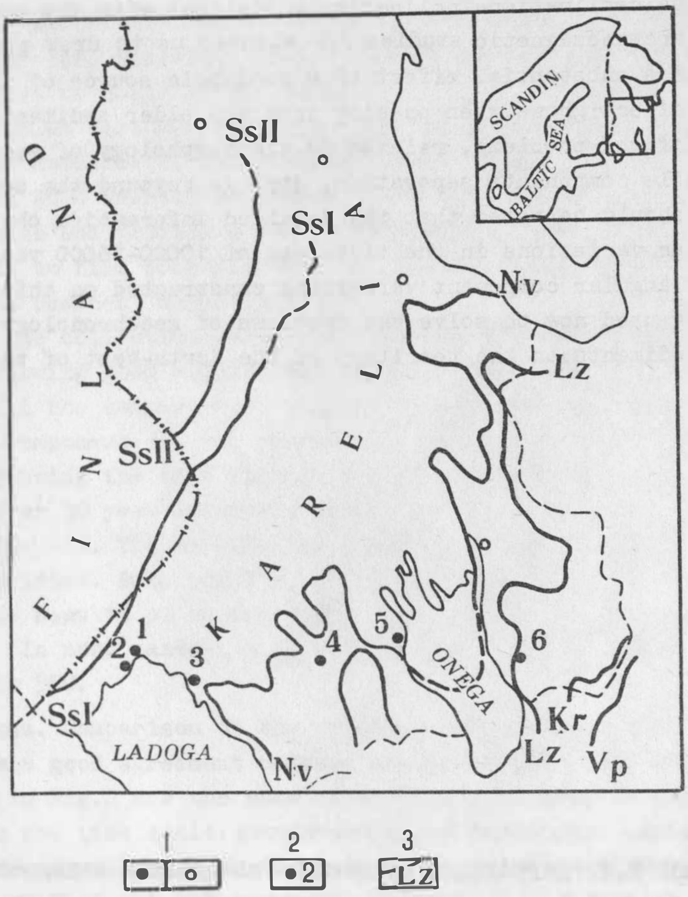

Fig.1. Margin scheme of the last continental glaciation stages in Karelia. 1 - objects of paleomagnetic studies; 2 - cross-sections of the varved clays (according to Fig. 2); 3 - margins of different stages of glaciation; V_p - Vepsa (maximum), 23 000 - 21 000 yrs. B.P.; Kr - Krestez, 17 000 - 15 000 yrs. B.P.; Lz - Luga, about 13 000 yrs B.P.; nv - Neva, about 12 000 yrs. B.P.;Ss-I - Salpausselkä I, about 10 700 yrs. B.P.; Ss-II - Salpausselkä II, about 10 200 yrs. B.P.

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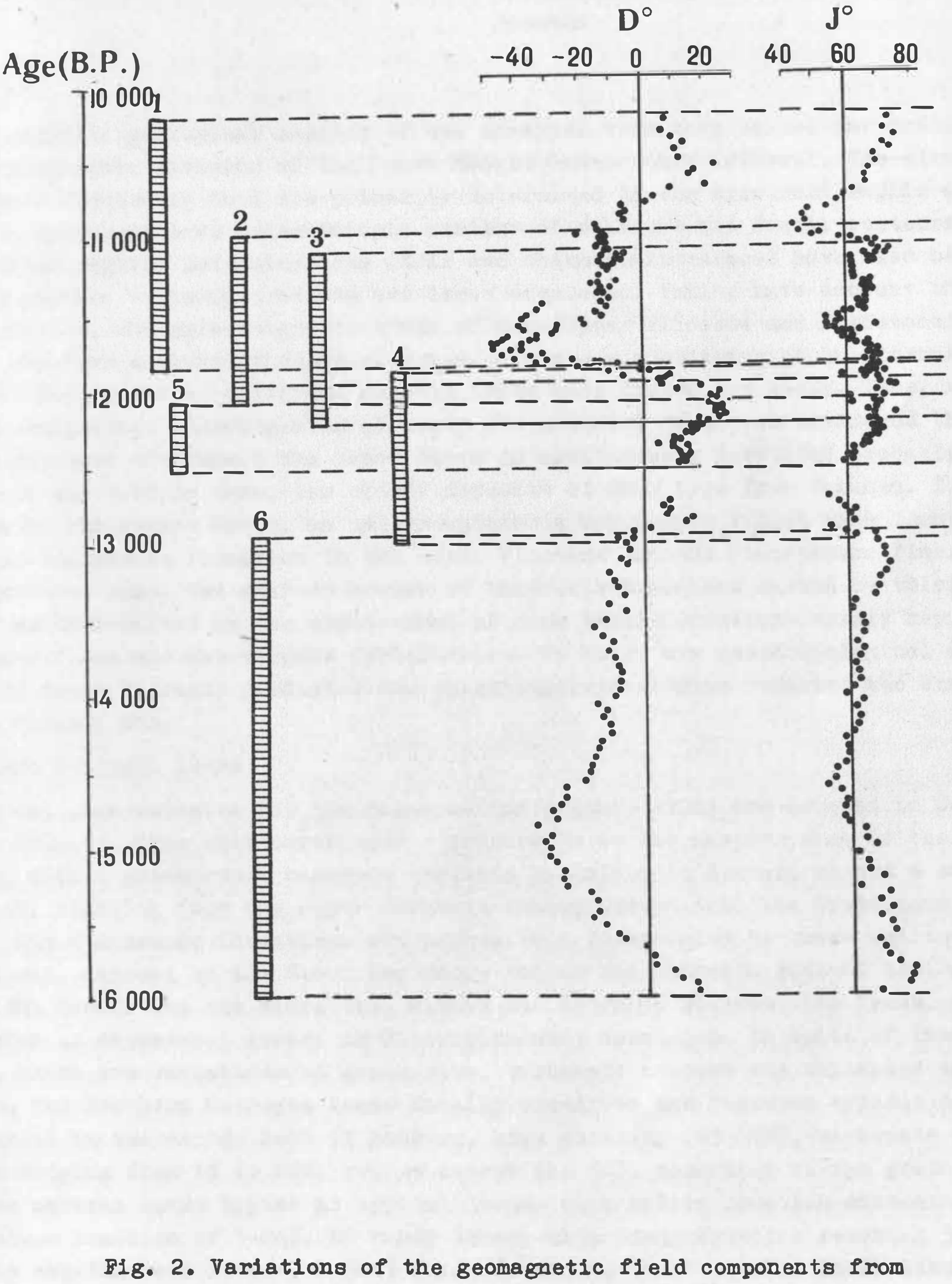

Fig. 2. Variations of the geomagnetic field components from the data of Karelian varved clays; D^{o}-declination, J^{o}-inclination.

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PALAEOMAGNETIC INVESTIGATIONS OF PLEISTOCENE FORMATIONS IN ROMANIA AND THEIR MAGNETOSTRATIGRAPHIC SIGNIFICANCE

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Introduction

The detailed geological mapping of the Romanian territory raised the problem of chronostratigraphic division of the Upper Neogene-Quaternary interval. The stratigraphic markers frequently used are primarily determined by the biostratigraphic data based on a representative paleontologic content of molluscs and fossil vertebrates. Some geochronological determinations (K/Ar and thermoluminescence) have also been performed on certain volcanic products and loess sequences. Taking into account these characteristics, the palaeomagnetic study of some Upper Pliocene and Pleistocene type-sections has been achieved these last years. Two areas consisting of Quanternary formations characterized by different genetic types were chosen for study. Thus, the magnetostratigraphic investigation of loess and paleosol sequences envisaged the southern Dobrogea area where the loess cover is continuously developed probably including, at the section base, the oldest deposits of this type from Romania. The second area is the Brasov Basin, an intermountainous depression filled with lacustrine and fluvio-lacustrine formation in the Upper Pliocene and the Pleistocene time. In the Pleistocene time, the western border of this depression was marked by volcanic activity which resulted in the emplacement of some basalt eruptions mostly represented by lava flows and subordinate pyroclastics. As there are geochronological determinations of these volcanic products, the palaeomagnetic studies regarded the eruptions from the Persani Mts.

1. Southern Dobrogea Loess

The sections selected for the magnetostratigraphic study are located in Southern Dobrogea (Fig.1). This unit coresponds structurally to the eastern area of the Moesian Platform, with a metamorphic basement overlain by Paleozoic formations and a sedimentary cover, starting from the Upper Jurassic transgression till the Cretaceous and the Neozoic. The Quaternary formations are exclusively represented by loess and loess-like deposits well exposed on the Black Sea shore and on the Dobrogea bank of the Danube. Between the Danube and the Black Sea, within the Dobrogea Plateau, the loess, chiefly accumulated in depression areas, is discontinuously developed. In spite of facies uniformity, there are variations of grain size, carbonate content and thickness of loess horizons. The Southern Dobrogea loess usually preserves the features typical of similar deposits in the world: lack of bedding, high porosity (45-50%), carbonate content commonly ranging from 15 to 20%, yellow colour (10 YR). According to the grain size, there are several loess types: a) typical loess, with siltic fraction exceeding 70%, argillaceous fraction of 5-25%; b) sandy loess, with sandy fraction reaching 50% and c) highly argillaceous loess (> 30%) which marks the transition to loess-like deposits. The loess-like deposits are polygenetic, as a result of the alteration of primary loess by syn- or postsedimentary processes.

The outcrops in the Black Sea coast and in central Dobrogea (characterized by com-

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plete sequences) show several loess horizons delimited by paleosols. At the top of the sequence there are three loess horizons delimited by two fossil soils, usually of chernozem type. They overlie a sequence characterized by alternating loess and argillic or argillic-illuvial paleosols. At the lower part of this sequence, the loess is altered, diagenetically transformed and the brown-red paleosols are difficult to recognize the top or bottom.

The loess and paleosol succession in Southern Dobrogea seems to point to climatic evolution characterized by two stages: a) a steppe stage, with low humidity and temperatures typical of periglacial areas, which favours the deposition of loess, while chernozem soils formed during precipitation periods; b) a stage marked by increasing annual precipitation and temperature and differentiated dry and humid periods, which favoured the growth of forest vegetation anf the constitution of brown-red argillic-illuvial soils. The cooling of climate accompanied by the reactivation of eolian dust resulted in the initiation of a new cycle of loess deposition.

The stratigraphic interpretation of this general view of Dobrogea climate shows that the brown-red argillaceous soils formed during the interglacial periods, while the chernozem soils represented Würm interstadials. The identification of seven fossil soils which break off the loess sequence led to the elaboration of a stratigraphischeme according to which the last paleosol is assigned to the Günz-Mindel interglacial (1). This stratigraphic image based on climate variations inferred from the study of different fossil soils cannot be related to the available archaeological data nor to palinological data.

These inconsistence implied additional investigations, such as the palaeomagnetic study of some characteristic sections of loess and paleosol sequences from Southern Dobrogea. The following sequences have been investigated starting from the Black Sea coast (east) to the Danube (west): A - Continesti, B - Nazarcea, C - Cuza Voda, D - Mircea Vodă, E - Cernavodă (Fig.1).

The results pf paleomagnetic studies are presented in figures 2 and 3.

The remanent magnetization was measured by the spinner-magnetometer JR-4 and the magnetic susceptibility and its anisotropy by Kappabridge KLY-1. The primary remance was isolated by Schonstedt TSD-1 thermal demagnetizer.

The diagrams which show the variation of palaeomagnetic parameters point out the normal polarity of all the loess and paleosol sequences investigated, corresponding to the Brunhes epoch. The available archaelogical data (Mousterian industry at Nazarcea-Ovidiu; Fig.3B) and thermoluminescence ones (13000±20000 years B.P., for paleosol III and 65000±90000 years B.P. for paleosol VI at Continesti; Fig.2AL)* confirm the paleomagnetic interpretation and account for the assignment of these formations to the Middle-Upper Pleistocene stratigraphic interval.

It is worth mentioning that at Nazarcea, the base of the loess and paleosol sequences exhibits along 4-6 m a horizon of red and grey clays with frequent gypsum fragments (Fig. 3B) which could stand for the Lower Pleistocene. This characteristic was also mentioned for the loess sections in Hungary (3).

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*) The thermoluminescence determinations were performed at the Laboratory of the Faculty of Geology, University Marie Curie-Sklodowska in Lublin (Poland), owing to Dr. E.Król from the Institute of Geophysics of the Polish Academy od Sciences in Warsaw, by using the samples collected during the international KAPG palaeomagnetic excursion in Romania (2).

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Considering the variation diagrams of magnetic parameters In and æ (before "magnetic cleaning"; Fig.2,3) it is to note the palaeoclimatic significance of the variations of intensity of natural remanent magnetization and of magnetic susceptibility recorded for the Southern Dobrogea loess and paleosols. Thus, the higher values of In and æ parameters of paleosols compared to those of loess are due to increased ferromagnetic mineral content of the former favoured by pedogenetic processes of paleosol constitution in humid climate and it high temperature, different from the loess deposition in cool and dry climate (4-6). Similar data have been reported by Fernex et al. (7) and Poutiers (8) with respect to Quaternary loess and paleosol sequences from France, and by Heller and Liu Tung-Scheng (9) regarding the Pliocene and Pleistocene loess and paleosol deposits from China.

2. Eruptions in the Persani Mts

The Persani Mts lie on the north-western border of the Brasov Basin, an intramountainous depression in the bend area of the East Carpathians. The depression basement of tectonic origin consists chiefly of Cretaceous flysch and several lithostratigraphic complexes from the Middle Pliocene till the Upper Pleistocene. The mentioned lithostratigraphic units are characterized by an illustrative fossil fauna similar to other characteristic assemblages from European basins. These allowed the elaboration of a magnetostratigraphic scheme, including the chronopalaeomagnetic interval Gilbert-Brunhes (10-13). Taking into account these data, the subsequent investigations were concerned with the north-western border of the basin built up of igneous products from the Persani Mts. The volcanic products are commonly represented by basaltic lava flows 2-20 m thick, pyroclastics, scoria and volcanic bombs. This sequence includes sedimentary rocks and lithologically complex successions resulted from terrigenous rocks associated with epiclastics and volcanic pyroclastics (vulcano-sedimentary formations). The relations between the basaltic lava flows and the volcano-sedimrntary complexes point to a lower volcano-sedimentary sequence delimited from an upper volcano-sedimentary sequence by basaltic lava eruptions. The sections studied by magnetostratigraphic methods correspond to the quarries from thw Bogata area and to the outcrops next to the Hoghiz locality (Fig.1). According to geochronological determinations (14) these eruptions were emplaced during the interval of 0.75 m.y. (Bogata) and 0.5 m.y. (Hoghiz). The boundary between Matuyama and Brunhes epochs placed in this period of time favoured the use of the palaeomagnetic method to separate the igneous and volcano-sedimentary formations. The results concerning the magnetostratigraphic position of basaltic eruptions and of volcano-sedimentary formations from the Persani Mts are rendered in Fig.4. The synthesis data show that the lower volcano-sedimentary sequence and the basaltic lava eruptions from Bogata area belong to Matuyama epoch, while the upper volcano-sedimentary formations and the Hoghiz basalts pointing to normal magnetization are assigned to the Brunhes epoch.

The magnetostratigraphic data obtained for the Southern Dobrogea loess deposits and the eruptions in the Persani Mts have pointed to the importance of the palaeomagnetic method to the elaboration of some local stratigraphic models assigned to general chronologic schemes of the Quaternary. The chronologic assignment of loess deposits in Romania was also achieved as part of the approach of this problem on global sclae.

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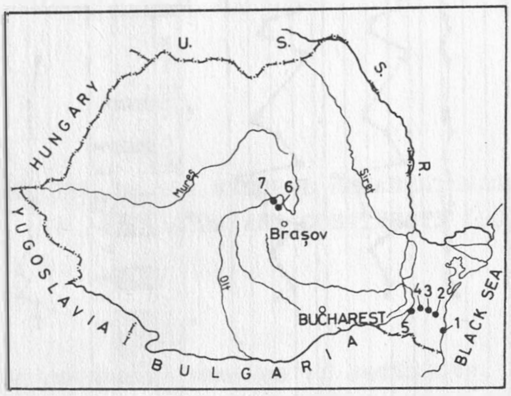
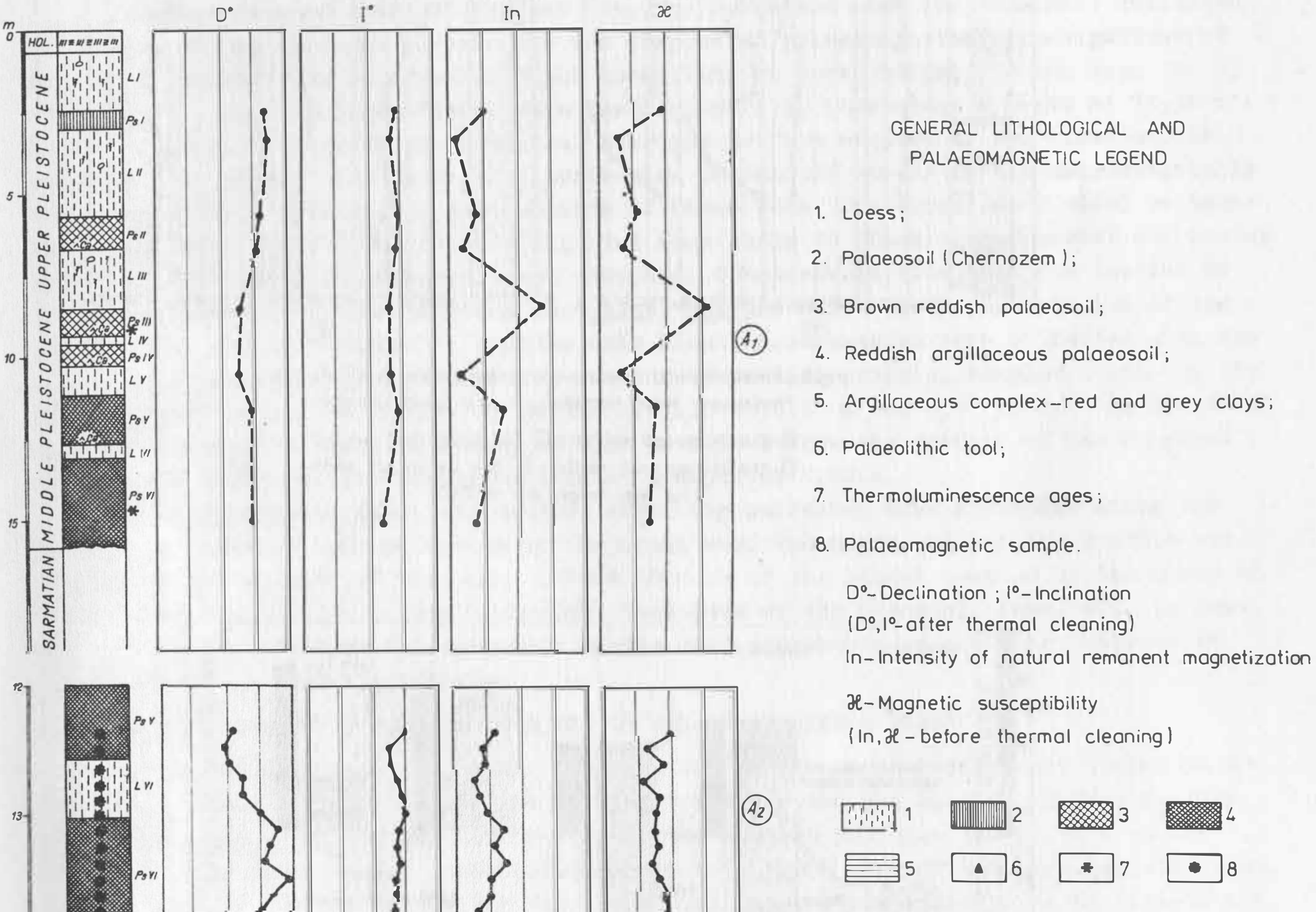


Fig.1 Location of the investigated sections

1.Costineşti 2.Nazarcea 3.Cuza Vodă
4.Mircea Vodă 5.Cernavodă 6.Bogata 7.Hoghiz



GENERAL LITHOLOGICAL AND PALAEOMAGNETIC LEGEND

1. Loess;
2. Palaeosoil (Chernozem);
3. Brown reddish palaeosoil;
4. Reddish argillaceous palaeosoil;
5. Argillaceous complex-red and grey clays;
6. Palaeolithic tool;
7. Thermoluminescence ages;
8. Palaeomagnetic sample.

D°- Declination ; I°- Inclination
(D°, I°- after thermal cleaning)
In- Intensity of natural remanent magnetization
ϰ- Magnetic susceptibility
(In, ϰ - before thermal cleaning)

A_1- The Costineşti section;
A_2- Detail in the lower part of the Costineşti section.

Fig. 2 Lithostratigraphic columns and palaeomagnetic results for Pleistocene loess formations in the South Dobrogea

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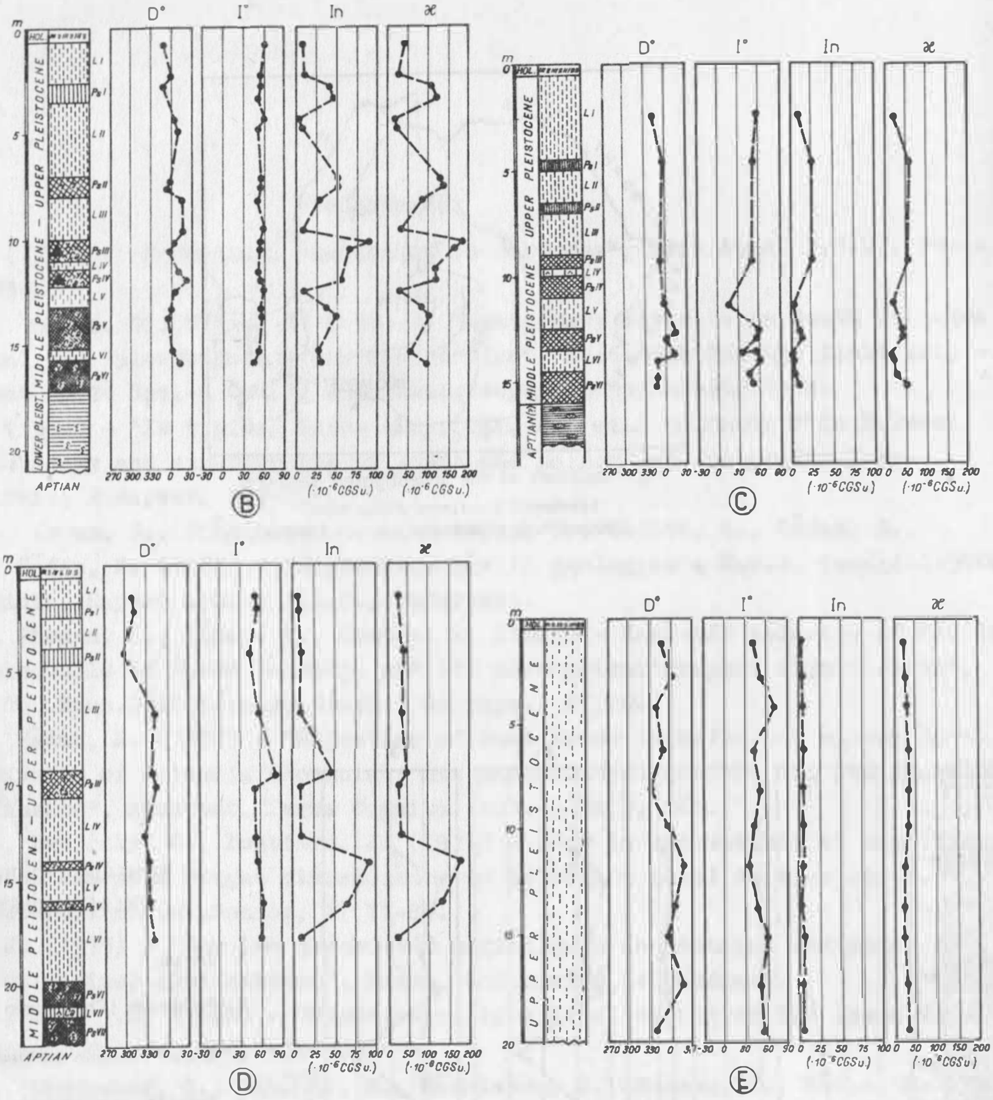

Fig.3 Lithostratigrafic columns and palaeomagnetic results for Pleistocene loess formations in the South Dobrogea

B-The Nazarcea section; C-The Cuza Vodă section; D-The Mircea Vodă section; E-The Cernavodă section. (for explanation see fig.2)

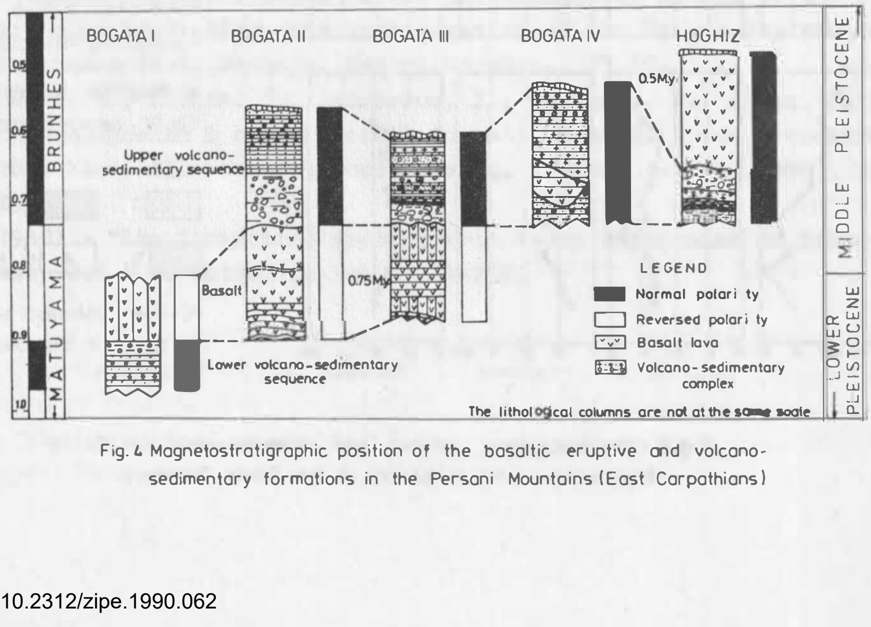

Fig.4 Magnetostratigraphic position of the basaltic eruptive and volcano-sedimentary formations in the Persani Mountains (East Carpathians)

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SPATIAL VARIABILITY OF THE NATURAL REMANENT MAGNETIZATION OF LOESSES IN CERNA VODA AND COSTINESTI (ROUMANIA)

Pagáč, P.

1. Introduction

While collecting palaeomagnetic samples of sediments, it is assumed that the vector of the natural remanent magnetization (NRMP) is the same at a particular level of sedimentation and, consequently, a sample of suitable size will be a good representation in the first approximation, of the layer as a whole. Check sampling is mostly carried out along parallel profiles, spaced as far apart as possible in order to reflect any lithological, tectonic and other changes in the extensive object being studied. Vertically continuous sampling is employed by studying rapid changes of the palaeomagnetic field (secular variations, the transition regime in inversions, during reversals events, excursions), or in sediments of small thicknesses.

The expedition of the KAPG Project 2 to the Dobrudzha area (SE Roumania) collected samples of loesses and palaeosoils for the purpose of palaeomagnetic investigations of the Upper Pleistocene. An oriented block (monolith) of rock, height 250 mm, base 120 by 110 mm, was collected just above a thin layer of pelite, located at a depth of 15,30 m below the upper surface of the exposure, near the profile sampled by Dr. P.Marton, in order to determine a more detailed distribution of the RMP vector in the macroscopically homogeneous layer of loess at the locality of Cerna Voda. The block was divided by horizontal sections into 11 plates (see Fig. 1a) from which 20 (from the uppermost and bottom most only 16) cubes, 20 mm cubed, were obtained. Considerable attention was devoted to the accuracy of the planes dividing the block, and the error in the orientation of the samples thus did not exceed 1°. Besides this block, also samples were collected with the aid of metal samplers along two short sections of another profile, sampled mostly by the other members of the expedition at depths of 3,90 to 4,30 m and 7,65 to 8,10 m. The first section was sampled twice at depths of 0,30 to 0,50 m from the surface of the original wall of the exposure, the second section at a depth of 0,40 m.

At the Costinesti locality, samples were only collected with a sampler along the profile at steps of 0,20 to 0,40 m in the usual way. The upper part of the profile was sampled in the SW part of the wall (about 60 m SW of the placed sampled by the group of Pazderkova, Dr. Chvojka of the Geological Institute of the Czechosl. Acad. Sci. in Prague), the bottom part at the SE margin of the land promontory at the place sampled by the other groups of the expedition.

2. Results of measuring the NRMP and RMP (5 mT) of the loess block

Before the first measurement of the RMP, the samples (and block) were stored in the in-situ position apart from the time they were transported and handled. Before further RMP measurements, the samples were stored in the inverse position for about 4 weeks. Later, all the samples were demagnatized by an A.C. field of 5 mT and then measured. The orientations of the RMP (5 mT) for the individual samples are illustrated in Figs 1b and 1c, which clearly show the large sactter of directions (see parameter k in Tab. 1).

In order to determine whether the RNP directions display some inertia in space, the mean directions were calculated for three systems (a,b,c) of smaller groups of samples (see Fig. 2, Tab.1). These systems were created by dividing the original block of samples by parallel planes at distance of 1 sample and with the normal pointing

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a) vertically (11 layers horizons: A,B,C,D,E,F,G,H,I,J,K),
b) N-S (4 zones: N, N2, S2, S).
c) E-W (5 sectors, E, E2, M, W2, W).

The coefficients of concentration k obtained in this way, indicate the considerable but differentiate scatter. In system b minimum k in zone N is affected mainly by the extreme directions G14, H15, I11, I12, J11, which distinctly decrease k also in the appropriate layers and sectors. The values of k in the other zones and all sectors vary between 8.0 and 15.7, i,e, close to the value appropriate for the block as a whole (k = 10.1).

One may expect a higher concentration of directions in the layers. This applies to horizons A to E and K. In viewing the graph of mean directions for the layers, it appears that the direction of the geomagnetic field changed along the loop KJIHGFE, resembling the secular variation. This part of the curve corresponds to layers with a lower value of k. It is still difficult to tell what the essence of this relation is, whether it is the result of a hitherto undefined quasi-random process, or whether it reflects the different behaviour of the geomagnetic field as observed in the loesses of the Tashkent region, where the scatter of the RMP directions in the part of the profile corresponding to the geomagnetic excursion was substantially higher than in the adjacent sectors where the direction of the field was stabilized. The magnitude of the RMP fluctuates considerably also in the average by layers, which is also evidence of the higher homogenety of the parameters in the horizontal direction. However, the RMP is distinctly higher in the sector of layers G to J. Since the values of the magnetic susceptibility are not available so far, this increase in RMP cannot be explained by using coefficient Q in connection with estimating the variation of the magnetic field intensity. Given the same volume magnetic susceptibility, the Q of this sector would be twice that of layer E.

If we consider the minimum and maximum values of RMP in layers

	A	B	C	D	E	F	G	H	I	J	K
min.	3.3	2.9	3.2	1.9	1.9	1.7	3.0	2.3	2.1	1.8	1.8
max.	6.2	5.8	5.6	4.8	3.7	5.2	9.2	9.0	7.9	11.7	6.4,

the sector GHIJ becomes anomalous only due to the part of the samples with higher RMP. A more detailed analysis will disclose a certain tendency to create clusters of samples with similar values of RMP. A similar tendency is also displayed by the RMP directions.

To conclude, we may summarize as follows: In the loess block the RMP directions display a considerable scatter which is distinctly lower if the block is divided into horizontal layers. It is probable that the mean directions of these layers are mostly affected by the secular variation or another variation of the geomagnetic field.

3. Results of determining the RMP along the Cerna Voda profile

Selected pilot samples were demagnetized in an A.C. field with a maximum indiction of 80 mT. The analysis of the directions thus obtained indicates two facts. Demagnetization at an induction of 5 mT is not always sufficient to eliminate the viscous RMP, induced in the reverse position of the sample over the 4 weeks. The magnetically hard component (RMP after demagnetization at 80 mT) in some samples displays a deviation of 10^{o} to 20^{o} relative to the normal field. The values of D,I and RMP (after demagnetization at 5 mT) are shown in Fig. 3a. The characteristic features, found in the loess block at a depth of 15.30 m, are manifest in a similar way: by distinct differences between the directions of the two collections, accompanied by a certain inertia trend.

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4. Results of determining the RMP along the Costinesti profile

The upper part of the profile (Upper Pleistocene) sampled at steps of 0.40 m yielded RMP directions exclusively of normal polarity (see Fig. 3b) with several deviations, mostly to the west. The largest deflection of the vector from the normal direction was observed in specimen C57; a considerable part of this deflection can be explained by the high percentage of viscous RMP, or by its residue after demagnetization at 5 mT. The magnitude of the RMP is distinctly affected by soil-forming processes: in the palaeosoils the RMP is roughly 5 times as large as in the loesses.

The specimens from the lower part of the profile (Middle Pleistocene) sampled at steps of 0.20 m also display RMP only of normal polarity. The hardest component in the pilot samples demagnetized at 80 mT was reflected in a small westward trend. The NRMP is very soft; under demagnetization at 20 mT the RMP decreases to 5-8% of the oridinal value. The NRMP of the palaeosoils is roughly twice as large as of the uintermediate loess layer.

5. Conclusion

The results of the palaeomagnetic investigation of the loess at locality Cerna Voda indicate the following:

a) a considerable scatter in the RMP directions of the separate samples;

b) distinct differentiation of the scatter according to the direction of the division;

c) the possibility of studying palaeosecular variations;

d) normal polarity along the profile investigated.

The main results for profile Continesti:

e) normal polarity along the whole profile;

f) RMP of the palaeosoils is 2 to 5 times higher than the RMP of the loess;

g) the NRMP contains a high percentage of the soft component;

h) the hard component in the NRMP displays certain deflections mostly with a mostly with a westward southward tendency.

Table 1

group	n	D°	I°	k	α_{95}	RMP/5/		group	n	D°	I°	k	95	RMP/5/	
horizon								zone							
A	16	349.3	60.8	54.4	5.0	4.503	0.873	N	53	354.6	56.7	6.3	8.5	3.561	1.069
B	20	7.5	63.7	35.3	5.6	4.189	0.797	N2	53	353.7	60.9	11.8		4.413	1.730
c	20	3.0	58.7	20.9	7.3	4.080	0.701	S2	53	351.7	64.3	11.8		4.561	1.836
D	20	357.1	60.6	14.2	9.0	3.064	0.813	S	53	347.1	67.4	15.7	5.1	4.815	1.731
E	20	0.4	60.4	23.7	7.0	2.777	0.511	sector							
F	20	2.3	46.5	9.9	10.9	3.135	0.906	E1	44	350.4	63.6	8.5	7.8	4.411	1.543
G	20	326.5	59.0	10.9	10.4	4.586	q.497	E2	44	357.3	60.8	9.7	7.4	4.241	1.377
H	20	301.4	68.8	8.7	11.7	6.060	1.866	M	44	349.4	63.2	11.9	6.5	4.407	1.743
I	20	334.2	71.4	4.6	17.6	5.415	1.805	W2	44	352.5	66.6	13.7	6.0	4.543	2.111
J	20	359.5	61.2	5.7	14.6	5.720	2.260	W	36	349.0	57.2	8.0	9.0	4.053	1.505
K	16	0.3	66.5	26.1	7.4	4.130	1.172							RMP/0/	
5 mT	212	351.8	62.6	10.1	3.2	4.342	1.675	0 mT	212	357.4	65.5	9.6	3.3	6.732	2.307

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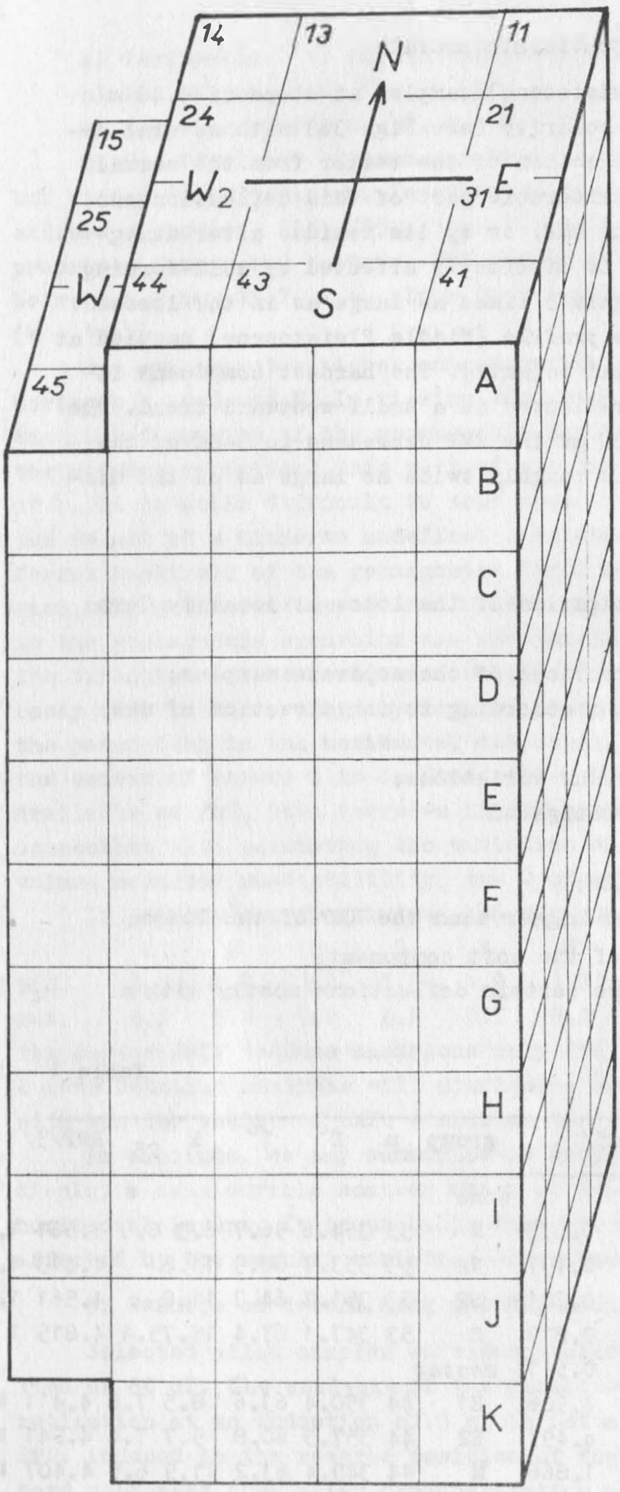

Fig. 1a. Orientation of the loess block, the division into cubes and designation of the main elements.

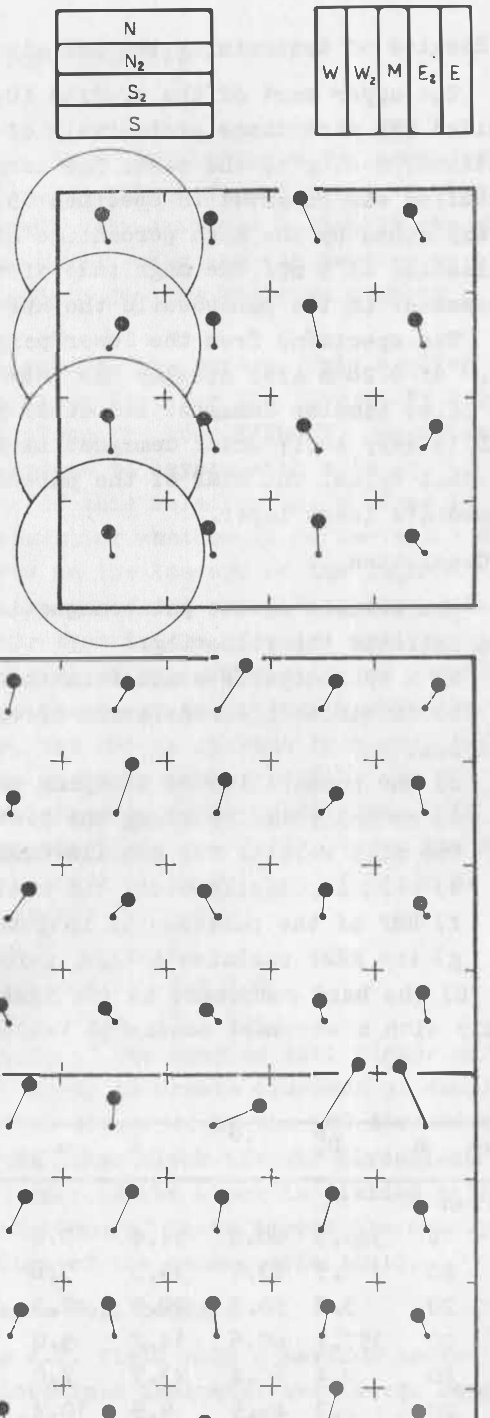

Fig. 1b, c. RMP directions /5 mT/ by horizons A to K. The circle defines the direction with inclination I = 0°. Black dots I > 0°, white dots I < 0°.

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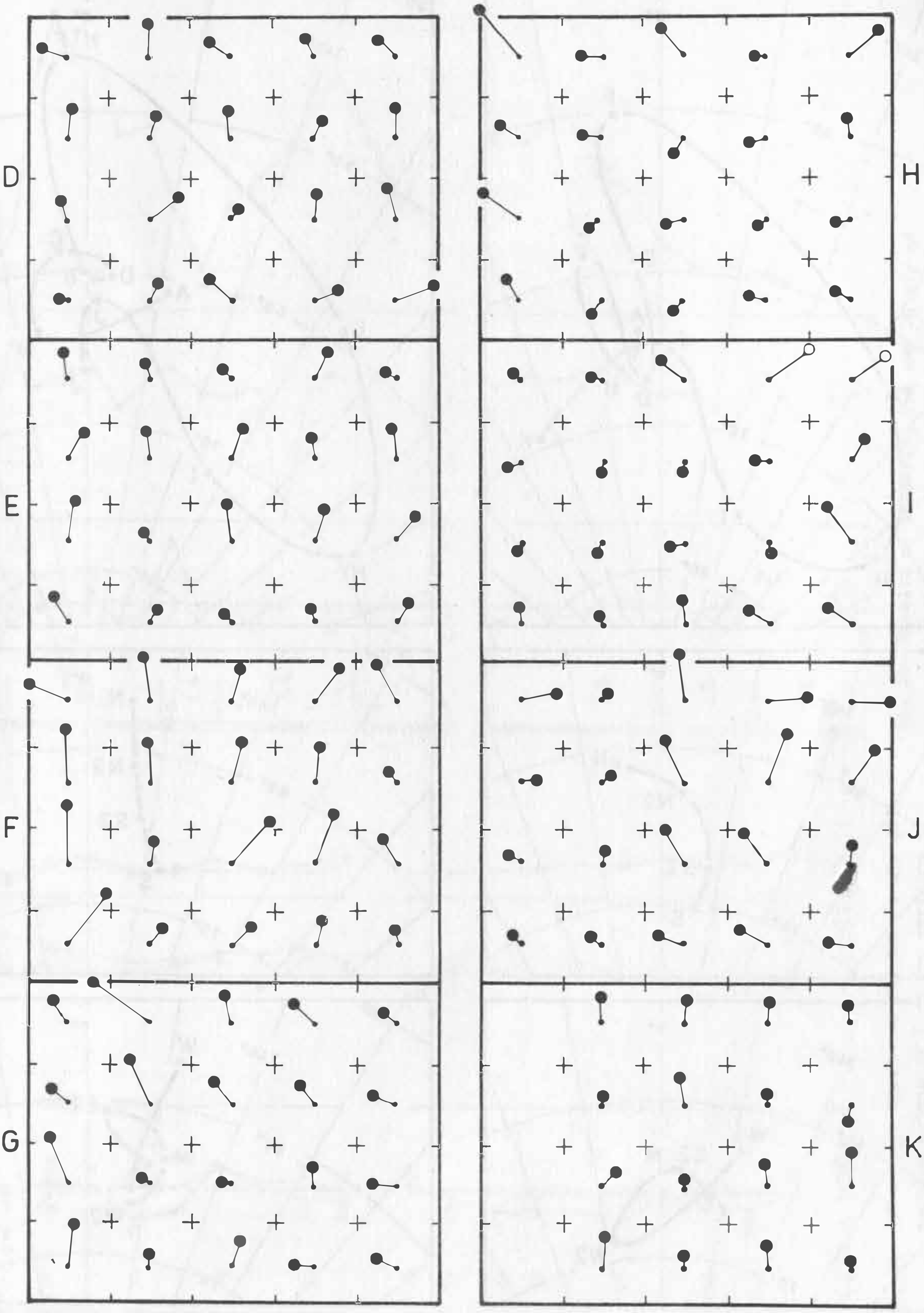

Fig. 1c.

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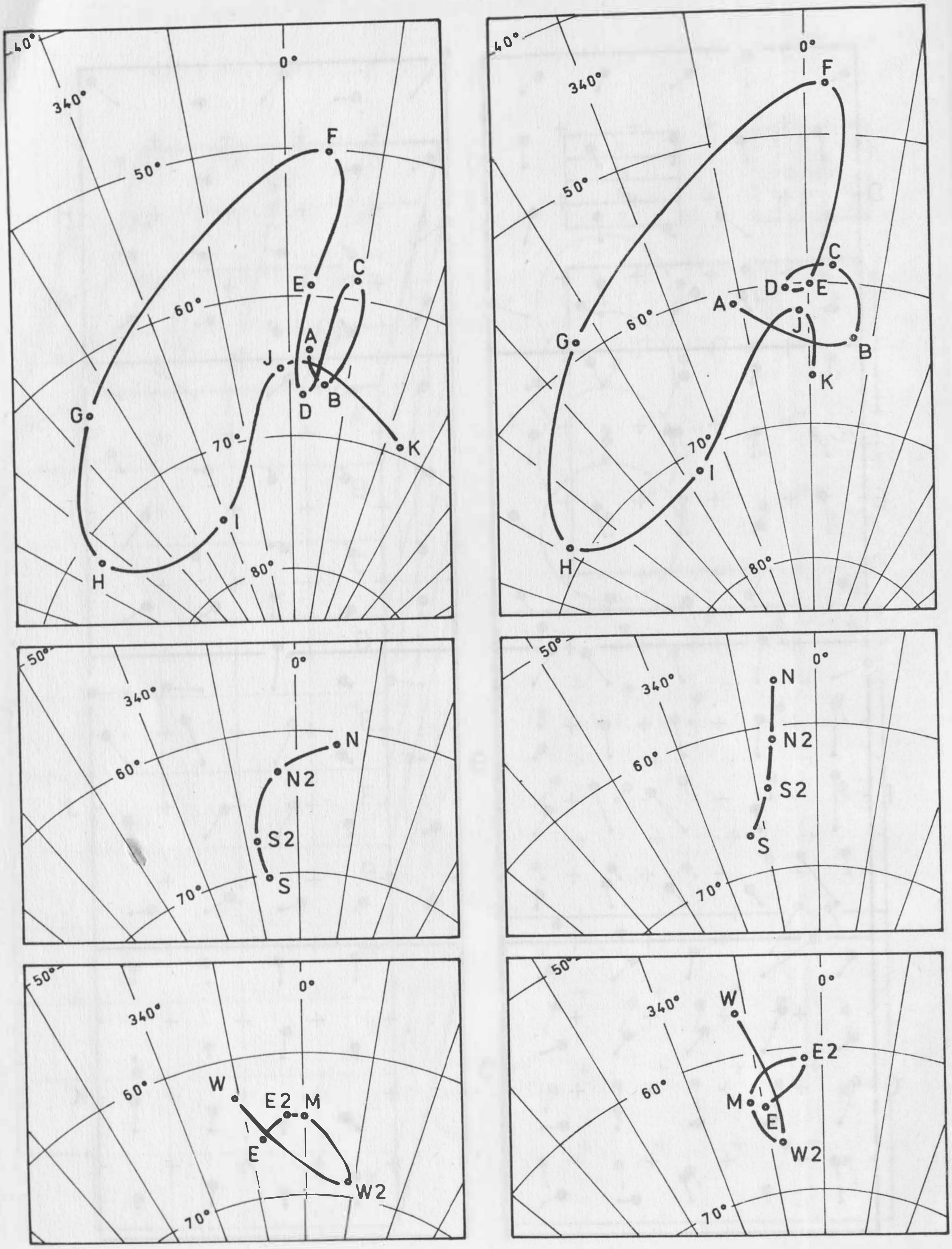

Fig. 2. Mean directions for horizons /upper part/, zones /middle part/, sectors /lower part/. NRMP /left-hand side/, RMP-5mT/right-hand side of diagram/.

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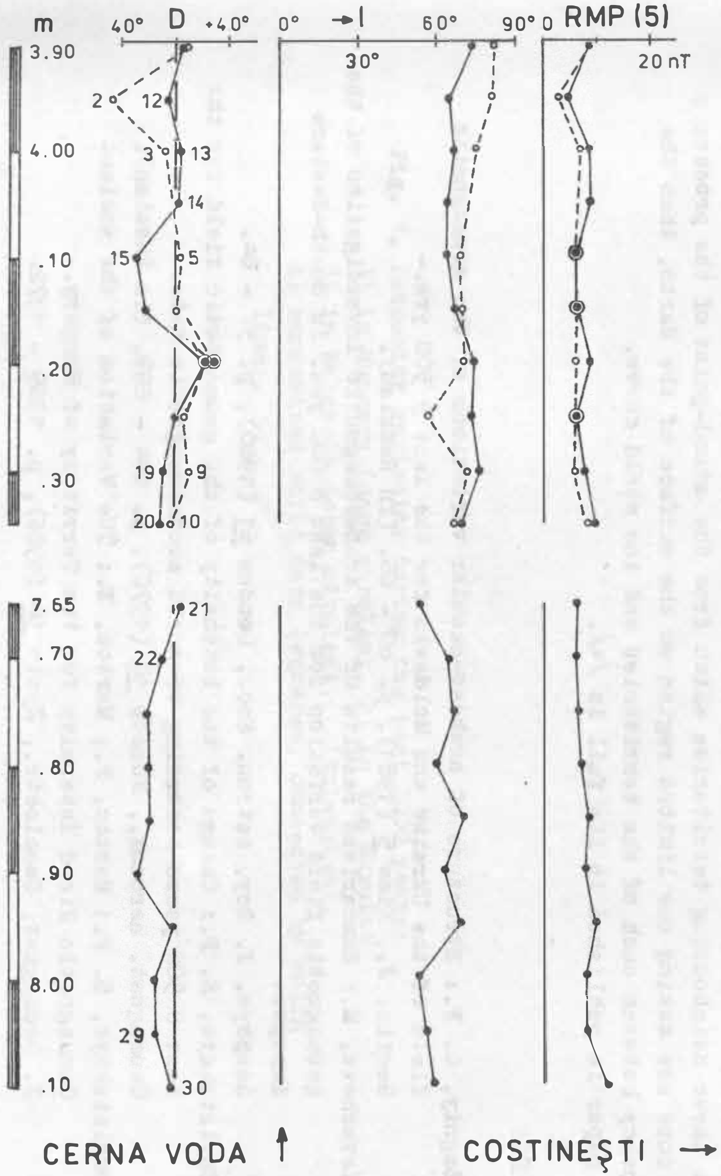

Fig. 3a. Results of measuring the RMP /5 mT/ of samples collected from two sections of the Cerna Voda profile.

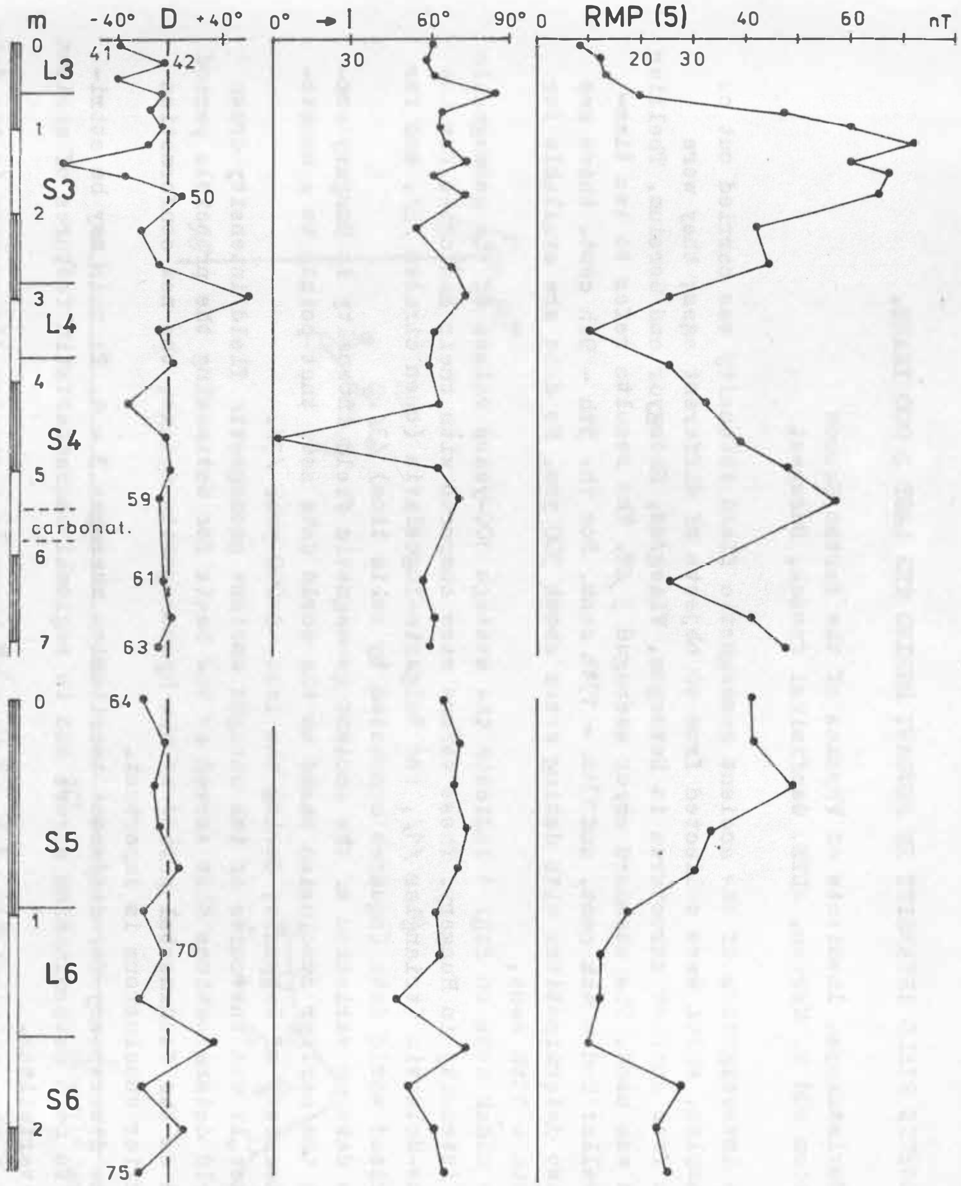

Fig. 3b. Results of measuring the RMP /5 mT/ of samples collected from two parts of the Costinesti profile. The depths are relative to the highest point of sampling.

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GEOMAGNETIC FIELD INTENSITY IN HUNGARY DURING THE LAST 2 000 YEARS.

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P. Marton and E. Marton, ELTE, Geofizikai Tansek, Budapest

The investigation of the ancient geomagnetic field intensity was carried out on the samples, which were collected from 40 objects of different ages; they were bricks from ancient structures in Estergom, Visegrad, Diósgyör and Gorsium. Thellier method was used. The standard error averaged 3 µT. The results refer to two time-intervalls: 2nd - 4th cent. and 13th - 19th cent. For the 5th - 9th cent. there are only two determinations with dating error about 300 yrs. No data are available for the 10th - 11th cent.

The black dots on fig. 1 indicate the average 100-years values of the geomagnetic field intensity in Hungary. These values were compared with their analogies for the Ukraine-Moldavia (triangles /1/, for Bulgaria-Yugoslavia (open circles /2/, and for summarized world data (squares connected by solid line) /3/.

The data on variation of the ancient geomagnetic field intensity in Hungary confirmed the earlier conclusion based on the world data set, that points to a monotonous decrease of intensity during the last 2 000 yrs. /3/.

Since it was the curve of the changed ancient geomagnetic field intensity drawn on world determinations that served as the basis for estimating the principle period viewed as the fundamental period of the hydromagnetic dynamo, the new conformation of earlier conclusions is important.

Data discrepancy for different territories averages 3 - 4 T; this may be attributed to both determination errors and to regional characteristic features of ancient field variations.

The latter is hardly feasible however as there is a greater discrepancy in the data for the three neigbouring territories which from the stand-point of the processes in the core are making one limited region on the surface of the Earth, than the discrepancy between each of the territories and the world curve.

The paper is published in its full in /4/.

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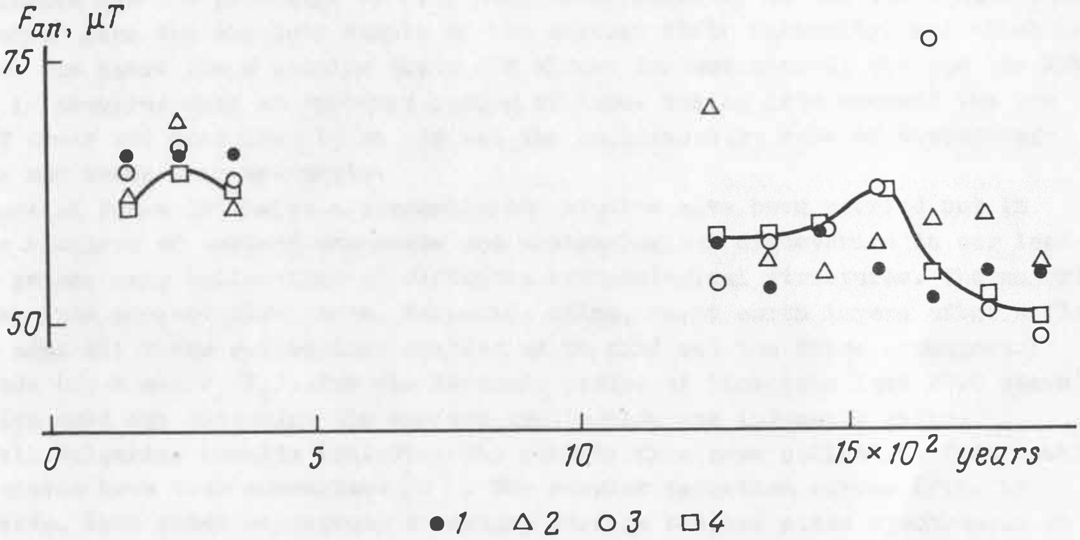

Fig. 1. Intensity variation during the past 2000 years:
1) in Hungary (dark circles), 2) in the Ukraine
3) in Bulgaria (open circles), (triangles),
4) summarized world data (squares, connected by solid line).

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ARCHAEOMAGNETIC RESEARCH IN BULGARIA AND THE FINE STRUCTURE OF THE GEOMAGNETIC FIELD

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One of the main objectives of archaeomagnetic studies is the construction of curves describing secular variations in both direction and intensity of the past geomagnetic field. The main difficulty in solving this problem is the relatively rare occurrence of suitable archaeological sequences with adequate chronologies. Here the research on the lake sediments has the privilege of long continuous records. On the other hand such a research cannot give the absolute values of the ancient field intensity. And which is more important the baked clays acquire their NRM almost instantaneously whereas the NRM of sediments is acquired over an extended period of time. Taking into account the recent works of Creer and Tucholka [1] we can see the complementary role of archaeomagnetic records and those from sediments.

In the last 18 years intensive archaeomagnetic studies have been carried out in Bulgaria. The richness of ancient monuments and archaeological discoveries in our land helped us to gather many collections of different archaeological structures. The majority of them are from ancient fireplaces, furnaces, kilns, burnt earth layers after a fire with a known age. All these collections enabled us to find out the three geomagnetic characteristics (I, D and F_A/F_D). For the historic period of time (the last 2000 years) bricks are also used for obtaining the ancient inclination and intensity ratio.

In 1980 all Bulgarian results including the results from some collection from Southeastern Yugoslavia have been summarized [2] . The secular variation curves (Fig. 1) cover 8000 years. Each point represents a century average between sites synchronous in time.
time. In order to fill up the gaps in our previous curves many new sites were examined, mainly from the prehistoric past [3, 4, 5] .

To reveal better the fine structure of secular variations, all results included in century averaged curves (Fig. 1) were revised in order to represent them as site means. On the other hand we wanted to give a weight to every individual result, as far as the intensity is concerned. Intensity is determined using the classical Thellier method [6] in a combination with the susceptibility measurements, which we carry out in the last few years. The difficulties which arise in the application of the above mentioned method oblige us to be very careful with the obtained results. First, the temperature interval of some Thellier experiment is chosen on the basis of the demagnetization curves, the old direction behaviour and the successive susceptibility measurements. Then, the ratio F_A/F_D is evaluated by the least square best fitted line. The weight of such an individual result is taken as an inverse variance of the above mentioned best fitted line. In Fig. 2 an example of the Thellier experiment is shown. The selected temperature interval is mentioned on the graph near to corresponding experimental points.

Once the site average values estimated, the question of their distribution on the absolute scale of time arose especially for the prehistoric past. It is well known already that the ^{14}C datings cannot give an absolute date in spite of their calibration because of the short term variations in the atmospheric radiocarbon concentration in the course of time. We consider as most valuable prehistoric sites used in our study the

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the multileveled ones, when a sufficient number of samples is collected from every level. The disposition of such results on the time scale according to their vertical stratigraphy is very helpful. Nevertheless the distribution of the obtained site means results is not regular. There are intervals of time which are very well covered with experimental data and others which are scarce. Fig. 3 shows the distribution of our revised intensity results for the last 2000 years. Each result is given with two bars depicting the experimental error (vertical) and the dating interval (horizontal). It is obvious that the picture is quite complex. The situation with the other two characteristics (the inclination and the declination) is quite similar. The only basic difference is that the data about the declination variation are much more scarce.

In order to draw out the sought for fine structure of the geomagnetic field, again a certain smoothing of the raw data is necessary. This smoothing has to reflect both the experimental errors and the length of dating intervals. We are just at the beginning of this state of our work and our previous results show that it is difficult to find out a common departure for the whole time interval studied (8000 years). The principal difficulty is that the accuracy of dating intervals is very different in the historic past (last 2000 yrs) from those in the prehistoric one. Also the available experimental data in the prehistoric past do not cover entirely the time scale and their distribution is more irregular. Thus the mathematical approaches have to be done separately. On the other hand this will again diminish the length of the studied interval of time.

Whatever approaches will be taken the most important thing is to have sure basic results distributed in the most accurate way on the absolute scale of time. We consider that in the near future our sequence of archaeomagnetic data will be sufficiently completed to represent a solid base for discovering the geomagnetic field fine structure.

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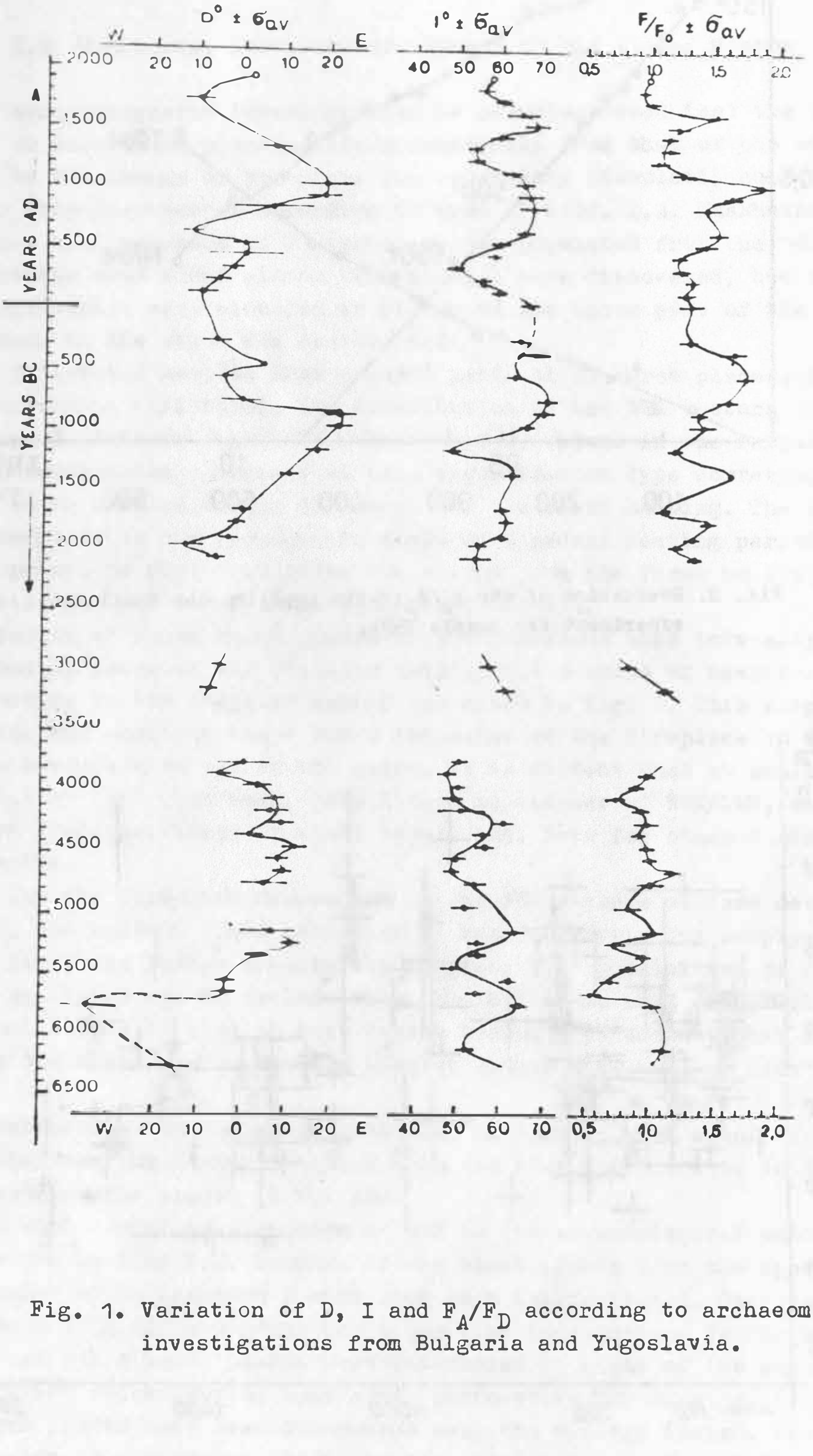

Fig. 1. Variation of D, I and F_A/F_D according to archaeomagnetic investigations from Bulgaria and Yugoslavia.

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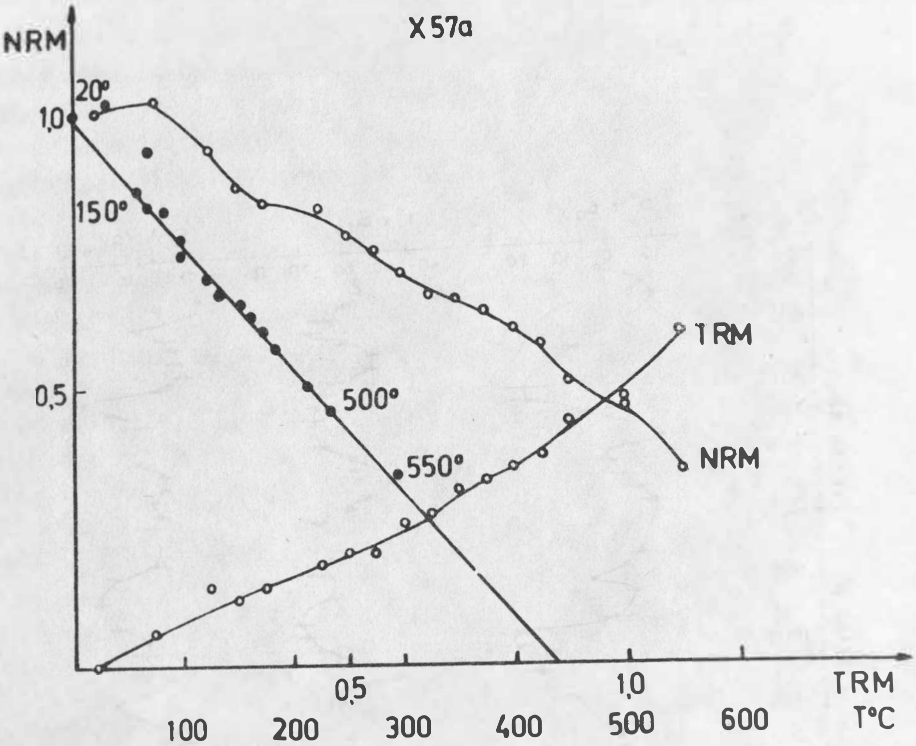

Fig. 2. Evaluation of the F_A/F_D ratio applying the Thellier experiment for sample X57a.

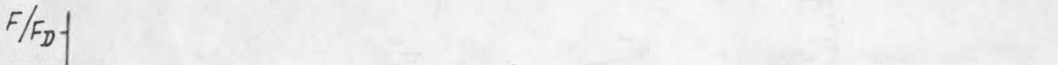

Fig. 3. Distribution of revised intensity data for the last 2000 yrs.

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ANOMALOUS BEHAVIOUR OF THE GEOMAGNETIC FIELD IN THE 1ST THOUSAND YEARS B.P.

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In process of archaeomagnetic investigations it was discovered that the direction of the magnetization of some baked places differs remarkably from that of the modern geomagnetic field up to the change of the sign. The Namchedury (Kabuleti) cult hill is characteristic for this phenomenon. According to data of Prof. D.A. Khakhutacshvili (chief of the digging) this hill consists of 7 strata and was populated from the 14th - 1st century B.C. In all strata some burnt places (fireplaces) were discovered, but anomalous directions of magnetization were recorded in places of the upper part of the third stratum only, dating back to the 9th - 6th century B.C.

We have taken orientated samples from central parts of 20 burnt places, in which clay looking like red bricks is well baked. The distribution of the NRM vectors of these samples is given in fig. 1. In some cases two magnetization vectors in one sample have been recorded. The high-temperature component of this magnetization type corresponds to the geomagnetic field which existed during the period of the first heating. The lower temperature vector corresponds to the geomagnetic field of a second heating period. Arrows between connected points in fig. 1 indicate the change from the first to the second direction of the magnetization for these samples with two vectors.

Another peculiarity of these burnt places is the anomalous high intensity of the magnetic field as defined by means of the Thellier method. The results of measurements of sample N 1712 according to the Thellier method are given in fig. 2. This sample is reliably orientated as during the sampling there was a cross-cut of the fireplace in which heating decreases from the surface down and to the sides. It is evident that at small changes of magnetic susceptibility (α) with heat, good linear dependence of NRM/TRM, constancy of the NRM vector ancient field intensity is equal 363±11 mkT. Data for other Namchedury samples are given in the table.

On the whole, for the direction dispositon of the NRM vectors western declinations D are characteristic, and maximum field intensity is characteristic for samples with inclination I close to zero. The latter peculiarity suggests the possibility of formation of the magnetization by lightning. To exclude this possibility we used a Z-gradientometer for analysing the magnetization of clay in this region taking into account that lightnings magnetize not only the burnt places but the unburnt either. However, we didn't discover such effects.

Laboratory experiments with thermodemagnetizing of samples with equal values of ARM, TRM and NRM show that the TRM curve is higher than the rest curves close to NRM. This fact testifies the thermomagnetic origin of the NRM.

Another object with anomalous direction of NRM is the archaeological memorial Pichory, dated to the 8th - 6th century B.C. Samples of the burnt places from the upper stratum (1) show a high dispersion of declination D with high mean inclination I. One specimen (N 2278) resembling specimen N 1702 of Namchedury has a negative inclination. In the non-digged area of this locality some other burnt places were discovered by means of the magnetic Z-gradientometer used for reconnoitring some areas perspective for digging.

Many other burnt places have been discovered near the village Tamish, one of them has negative magnetization. A comparable place has been recorded near Zugdid town. According to the measured field gradient these places lie 0,5 m below the surface. They have been

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dated preliminary to the 8th - 6th century B.C.

High preferable western deviations of the declination D are discovered in material of hearthes from Narekvavi (eastern Georgia). Thus the data obtained confirme apparently the fact discovered by Folgerhaiter during the investigation of the magnetization of Etruscan vases, that the geomagnetic field was reverse at any time during the 8th century B.C. and indicate that a large region at last between Italy and the Caucasus was affected by this phenomenon. However, the absence of precise dating of the investigated material in the Caucasus doesn't permit not only to trace this phenomenon in detail but also to define its exact age. Statistically from all available data for the 9th - 6th century B.C. only the continuance of the disturbed field during some decades can be approximately defined.

The importance of investigation of this phenomenon is evident. The number of archaeological definitions must be widen both in the regions were this phenomenon has been discovered and in other regions for the solution of the problem on the global or regional character of the given datum. All available burnt places of that time should be chosen and investigated for this purpose.

Table Results of archaeomagnetic investigation of the specimens from sites Namchedury and Pichory: declination D, inclination I and intensity of the ancient magnetic field B. When two vectors are in the specimen, parameters of the field at low temperature (lesser than 350^o) are given in brackets. ± standard error of the mean.

Site, data Number of specimen 1	D^o 2	I^o 3	$B_{anc.}$ ± 4
Namchedury 9th - 6th cent. B.C.			
1010	268 (264)	-65 (-20)	71,9±1,9 (148,2±4,6)
1011	281	-2	760,0±52
1012	324 (256)	58 (20)	61,7±2,7 (197,0±11)
1695	71	-52	78,7±2,3
1696	310 (320)	-61 (-54)	75,2±0,6 (72,1±2,2)
1697	352 (358)	-3 (16)	73,5±1,9 (83,8±0,9)
1698	337	57	75,3±0,7
1699	163	-60	75,8±1,1
1700	308	75	74,2±0,3
1701	25	-50	69,3±1,0
1702	262	0	66,5±0,3
1703	2	39	80,0±0,3
1704	352	49	76,3±1,0
1705	19	27	70,6±0,7
1708	135	72	74,4±1,0

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1	2	3	4
1709	69	-35	75,0±2,0
1710	335	41	76,2±0,6
1711	270	43	78,9±1,9
1712	340	-12	363,0±11
Pichory 7th - 6th cent. B.C.			
2218	58	70	74,7±0,7
2219	76	83	80,8±1,2
2220	100	81	80,3±0,6
2275	237	85	71,6±0,9
2276	314	72	80,8±0,6
2278	260	-11	80,2±0,9
2281	12	68	82,7±0,6

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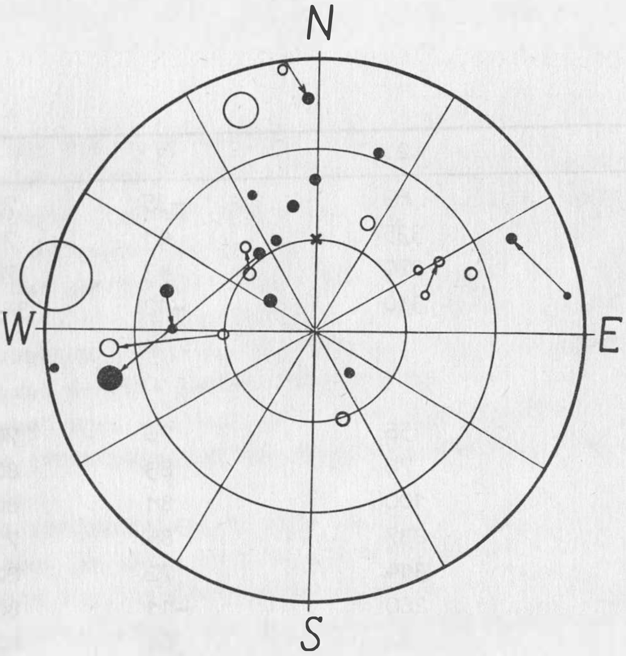

Fig. 1. Distribution of the NRM vectors of baked clays of the Namchedury cult hill. Open circles - negative inclination, closed circles - positive inclination, cross - modern field direction at the site.

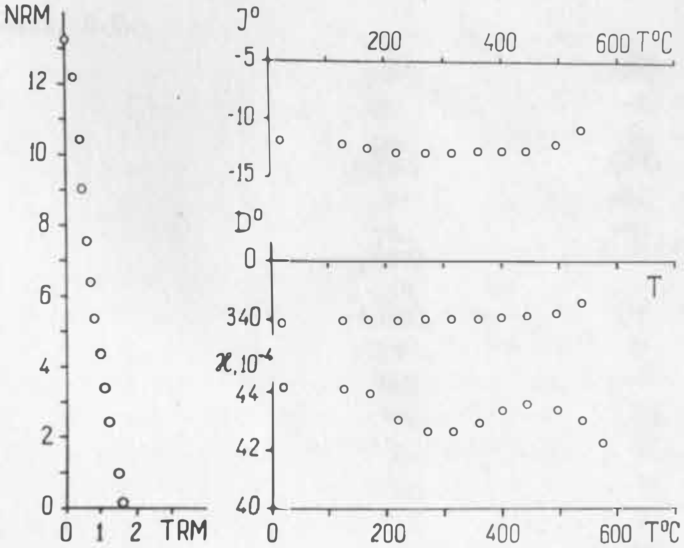

Fig. 2. Specimen N 1712: NRM-TRM diagram. Variation of inclination I, declination D and magnetic susceptibility ϰ with temperature. Increasing TRM in fields of 50 mkT.

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PALEOMAGNETIC INVESTIGATIONS OF THE LOWER PLIOCENE SEDIMENTS FROM SOUTHERN BULGARIA

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The investigation of the geomagnetic field during the Pliocene is of important scientific and applied significance. During the Pliocene three geomagnetic epochs have been established: [1, 2, 3, 4] Matuyama (R) with absolute age 0,72 - 2,47 my, Gauss (N) - 2,47 - 3,41 my and Gilbert (R) - 3,čl-5,44 my. Each geomagnetic epoch contains short-term geomagnetic episodes with an inverse polarity with respect to the epoch, which are well studied and dated. These geomagnetic episodes find out a possibility for dismembering and paleomagnetic age correlation of rocks with unknown age.

In 1981 the authors collected a set of samples (clays) of the so called gravel-sand-clay geocomplex in Southern Bulgaria [5]. In the Upper Thracian depression this complex has a total thickness to 500 m and is presented by gravels, sands, clays and lignite coal. The found fossil fauna and flora determine the age of the geocomplex as a pliocenic one [6]. The sediments of the gravel-sand-clay geocomplex are formed in freshwater lake basins of a valley type [5].

The samples with numbers from 1 to 35 are gathered by means of non-magnetic wedges of three parallel profiles at a distance 20-30 m from each other in the upper part of the clay quarry near the town of Harmanli. The vertical distance of the samples from each other is about 10 cm so that the maximal thickness included is about 1,30 m. The samples are oily clays, brown in colour, which upwards in the section pass into sandy clays of the same colour. The supposed age is lower Pliocene (Pontian ?).

The samples with numbers from 36 to 55 are also gathered with wedges from two parallel profiles at a distance 30 m from each other in the open mine for lignite coal at the village of Obruchishte (upper over-coal horizon). They are oily grey-bluish clays which up in the section pass into faintly welded sandstones. Their supposed age is Maeotian-Pontian.

The laboratory paleomagnetic investigations of the samples included:

1. Measurement of J_n with a spinner magnetometer JR-4 three times: after bringing the samples in the laboratory, after keeping them along the geomagnetic field 45 days and against the field 90 days.
2. Measurement of the magnetic susceptibility $\varkappa$ by a kappa-bridge KLJ - 1.
3. Temporal cleaning 90 days.
4. Temperature cleaning - 100°C.

The results of these measurements showed that the clays from the quarry near Harmanli possess a faint natural remanent magnetization J_n which varies within the boundaries of 0,21 to 1,16 nT (average 0,49 ± 0,21 nT). Their magnetic susceptibility $\varkappa$ is within the boundaries of 179 to 295.10^{-6} SI (average 219 ± 29.10^{-6} SI) and Q - the factor from 0,02 to 0,29. In the upper part of the three profiles where the clays pass into sandy clays an abrupt increase of the J_n and $\varkappa$ values is observed ($J_n$av = 5,20 ± 0,63 nT; $\varkappa$ av = 590 ± 167.10^{-6} SI).

The analysis of the J_n directions according to the original measurements showed that in the profiles there are normally inverse and anomalously magnetized samples. With the purpose to clean the secondary magnetizations a temporal and thermal cleanings were made. After keeping the samples 90 days against the geomagnetic field some of them

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(mainly of the I and II profile) change the J_n direction and turn out to be inversely magnetized. The size of the viscose magnetization varies in large boundaries - from 0 to 48% from J_n (average $\frac{J_{rv}}{J_n} = 0,22 \pm 0,12$). The least possible magnetization (0 - 0,17% of J_n) is observed in the upper part of the profiles, where the samples posses an inverse magnetization "in situ".

The thermomagnetic cleaning at 100°C confirms, to a certain extent, the results of the temporal cleaning. The inversely magnetized "in situ" samples preserve their inverse magnetization. In some of the samples with low inclinations after a thermal cleaning an inverse magnetization is found out. The intensity of the natural remanent magnetization J_n after the thermal cleaning at the inversely magnetized "in situ" samples from the upper part of the profiles usually grows (107-130% from J_n), which is explained with the cleaning of the viscose magnetization with a normal polarity. In the remaining samples (with normal and anomalous polarity) the intensity of J_n decreases (from 35% to 90% from J_n). After the thermal cleaning the mean value of the J_n intensity is $J_n av = 0,37 \pm 0,25$ nT (for the normally and anomalously magnetized samples) and $J_n av = 4,87 \pm 1,99$ nT (for the inversely magnetized ones).

These results from the laboratory paleomagnetic investigations give us grounds to suggest that the clays from the region of Harmanli contain magnetite (in the upper part of the profiles), hematite and magnetite and iron hydrooxides (the rest of the samples). It can be supposed that the clays possess three types of remanent magnetization: orientation, chemical and viscose ones. The primary magnetization of the samples of the profiles largest part is formed in a geomagnetic field with inversed polarity. The inverse polarity with some of the samples is covered by the viscose magnetization J_{rv}. The final results are presented in Tab. 1 and Fig. 1.

The clays from the region of the open mine at the village of Obruchishte possess a weak natural remanent magnetization - from 0,29 to 0,87 nT (average value $0,55 \pm 0,15$nT). Their magnetic susceptibility $\varkappa$ is of 95 to 157.10^{-6}SI (average value 135 ± 17.10^{-6}SI) and Q - the factor is small - from 0,02 to 0,08.

The analysis of the J_n directions along the original measurements showed that all samples are normally magnetized. After the temporal and thermal cleaning up to 100°C the J_n directions are not significantly changed. A more stable element is the inclination of J_n. The size of the viscose magnetization varies within the boundaries of 20% to 36% from J_n (average $J_{rv}/J_n = 0,27 \pm 0,05$). After the thermal cleaning the average value of the J_n intensity is $J_n av = 0,25 \pm 0,10$ nT).

As seen from the average values of J_n and $\varkappa$ the samples from the both profiles indicated above are magnetically homogeneous. They contain magnetite and their original magnetization is formed in a quiet period of the geomagnetic field with a normal polarity.

The final results from the laboratory paleomagnetic investigations of these rocks are presented in Tab. 2 and Fig.2.

Here we should note that the samples from the different profiles presented in Figs. 1 and 2 are not at one and the same hypsometric level. The samples from each profile have an independent position in the section. It is possible to make a correlation among the three profiles at Harmanli by J_n size and direction, but such a correlation is not made. The two profiles at the village of Obruchishte cannot be juxtaposed because of the near values and directions of J_n.

Table 3 presents the coordinates of the paleomagnetic poles separately for the clays at Harmanli and the ones at Obruchishte as well as the coordinates of the common paleomagnetic pole, calculated along the J_n directions after a temporal cleaning, and in Table 4 - after a thermo-cleaning. As seen from the tables the grouping of the virtual

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geomagnetic poles is better after the thermocleaning. The coordinates of the paleomagnetic pole for the two revealings very well agree with the coordinates of the paleomagnetic pole determined by the investigations of the Pliocene basalts in Northern Bulgaria ($\phi = 82^{\circ}$, $\Lambda = 143^{\circ}$E).

On the basis of the obtained results from the laboratory paleomagnetic investigations, the following more important conclusions can be drawn:

1. The clays from the quarry at Harmanli with a supposed age Pontian are magnetized normally, inversely and anomalously and are probably formed during the geomagnetic epoch Gilbert (R). A more exact dating is possible after detailed paleomagnetic investigations of samples from the whole section.

2. The clays from the open mine for lignite coals at Obruchishte are magnetized only normally and are probably formed during the geomagnetic epoch 5(N). Their age can be determined as Maeotian. Here too more detailed paleomagnetic studies of samples from the whole section are needed.

In conclusion we should note that the results of the paleomagnetic investigations of Pliocene sediments in Bulgaria presented in this paper are a first attempt in this field. In future these investigations will continue and will include also other sections of Pliocene and Quaternary sediments in Bulgaria.

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Harmanli - I profile						Harmanli - II profile						Harmanli - III profile					
	viscous cleaning			VGP positions			viscous cleaning			VGP positions			viscous cleaning			VGP positions	
No	D^o	I^o	J_n (nT)			No	D^o	I^o	J_n (nT)			No	D^o	I^o	J_n (nT)		
9	6	-3	1,71	46	198	22	38	80	4,46	56	49	35	112	33	3,98	-3	89
8	166	-64	6,76	-79	140	21	167	-13	5,76	-53	47	34	193	-8	5,63	-50	5
7	76	-70	1,03	-25	166	20	180	-39	6,24	-70	25	33	223	19	0,43	-25	338
6	32	-7	0,15	36	165	19	254	15	0,21	-7	313	32	219	50	0,95	-9	353
5	64	-24	0,28	11	143	17	164	-28	0,17	-60	302	31	136	49	0,27	-7	63
3	83	64	0,34	33	82	16	198	-29	0,24	-59	351	30	169	75	0,33	14	32
2	22	-9	0,33	39	177	15	203	-17	0,26	-51	348	29	211	6	0,33	-37	347
1	11	-5	0,28	45	191	12	221	55	0,35	-4	353	28	354	62	0,31	86	308
						10	210	-26	0,12	-52	334	27	287	45	0,30	30	306
												26	265	16	0,70	2	305
												25	40	67	0,25	61	87
												24	96	41	0,35	11	94
												23	198	41	0,21	-23	8

TABLE 1

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	Maritza - Eastern - I profile						Maritza - Eastern - II profile				
	viscous cleaning			VGP positions			viscous cleaning			VGP positions	
No	D°	I°	J_n(nT)	Φ	Λ	No	D°	I°	J_n(nT)	Φ	Λ
46	317	69	0,32	60	329	55	256	43	0,17	7	323
45	321	74	0,32	60	347	54	285	78	0,16	44	354
44	328	53	0,21	64	288	53	273	69	0,21	34	338
43	290	70	0,35	44	335	52	264	68	0,23	28	341
42	313	51	0,41	51	296	51	275	61	0,29	30	327
41	347	64	0,36	80	318	50	278	63	0,33	33	328
40	352	47	0,38	74	234	49	59	67	0,18	49	84
39	344	65	0,50	78	324	48	326	67	0,35	65	326
38	335	61	0,36	72	304	47	298	63	0,34	46	321
37	358	55	0,54	83	218						
36	345	72	0,49	72	359						

TABLE 2

TABLE 3

After viscous cleaning						
site	age	N	D	I	K	α_{95}
Harmanli	pliocene	21	176,9	66,0	4,3	17,3
Maritza- Eastern	pliocene	19	330,6	61,0	9,9	11,1
Jujna Bulgaria	pliocene	40	279,1	82,8	4,0	13,0

TABLE 4

After thermocleaning						
site	age	N	D	I	K	α_{95}
Harmanli	pliocene	18	157,0	64,8	4,5	18,1
Maritza - Eastern	pliocene	18	12,4	85,6	21,1	7,6
Jujna Bulgaria	pliocene	36	148,2	80,4	6,3	10,2

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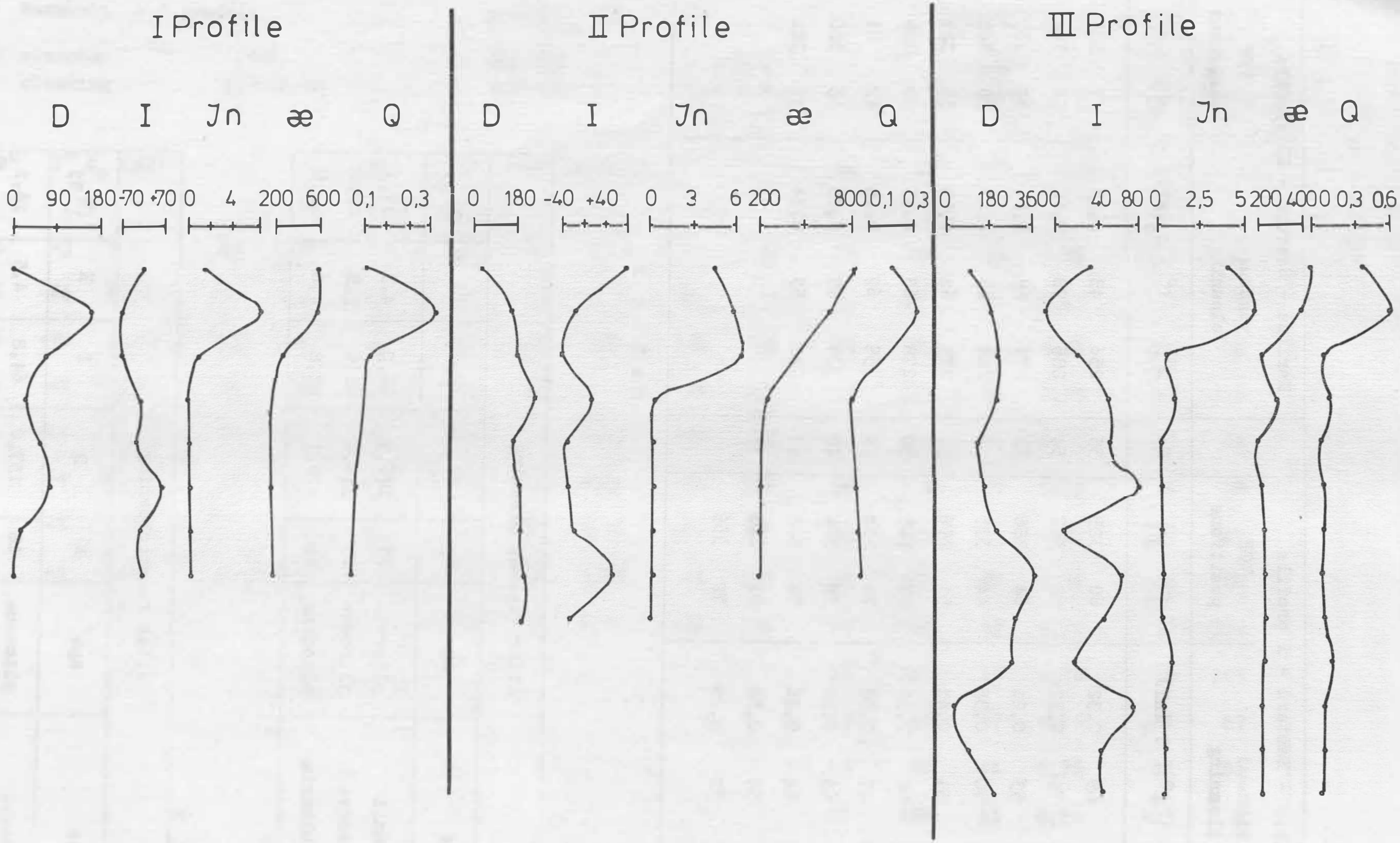

Fig. 1. Petro-palaeomagnetic characteristics of lower Pliocene sediments from three sections near Hermanli.

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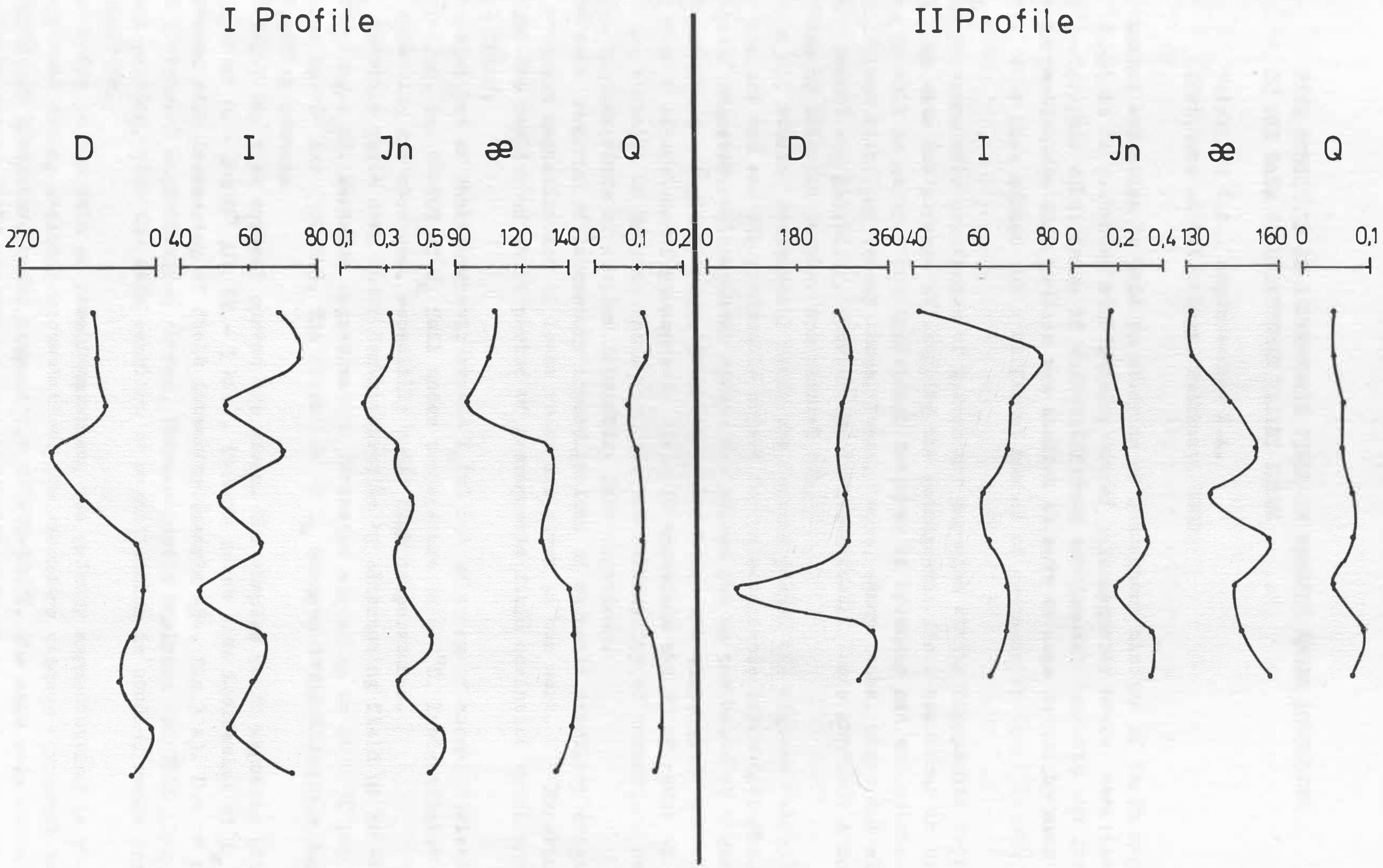

Fig. 2. Petro-palaeomagnetic characteristics of the Maeotian-Pontian clays from the open mine of Obruchishte.

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FINE STRUCTURE OF GEOMAGNETIC FIELD IN BRUNHES EPOCH ACCORDING TO THE DATA OF ZERAPHSHAN VALLEY LOESS

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A special attention is paid to studying of Quaternary history of Earth magnetic field. First of all it is connected with working out of paleomagnetic scale, neccessary for detail stratigraphic subdivision of unfossiliferous continental deposits and for loess strata in particular. This problem was studied in more or less detail by many investigators. They have marked out a different number of geomagnetic field events in Brunhes epoch.

The paleomagnetic researches of Quaternary deposits within Zeraphshan depression were carried out with the purpose of studying the geomagnetic field behaviour in stationary regime, as well as general and individual features of episodes and excursions. The rocks with different lithology (stony loess, loess, loams, sandy loams, clays and slightly cemented sands) and genesis (proluvial, proluvial-alluvial) were studied. A continuous collection of oriented samples was carried out.

Among all studied sedimentary rocks the loesses posses the highest values of magnetic parameters and are the preferable object for paleomagnetic investigations.

A local magnetostratigraphical scheme was worked out on the basis of these investigations and then a regional magnetostratigraphic scheme was elaborated According to this scheme 6 excursions of geomagnetic field (3 anomalous and 33 of reversed declination) were revealed in Brunhes epoch (fig.1). The reliability of excursions revealed is based on the materials of complex laboratory investigations.

The main results of laboratory investigations of magnetic stability origin of natural remanent magnetization of loess rocks are given in our work. Experimental data confirmed the reality of short period of geomagnetic field deviation which are described in this paper.

The examples of thermomagnetic curves $I_n(t)$ out of zones of anomal deviation are given in fig. 2a. 60-70% of I_n fail under temperature of 600^oC. Insignificant changes in I_n direction are observed, especially under high temperatures.

I_n smoothly falls down under demagnetization by alternating field up to 48.10^3 A/m (600 oe) (fig.2 b). Remanent magnetization decreases almost up to 40 - 50 per cent in fields of 24.10^3 A/m (300 oe). The direction of I_n changes insignificantly during the demagnetization process.

In fig.3 the most typical curves are given. The samples reach magnetic saturation in fields of 16 - $24x10^4$ A/m (2 - 3 kOe), in some cases slow increasing of I_r value is observed with increasing of field intensity (sample 454, fig.3 a). Due to the character of isothermal magnetization curves, thermomagnetic analyses and TDMA (fig. 3c), it can be concluded, that the main carriers of magnetization in studied rocks are magnetite and haematite.

According to the data of resedimentation, the primary magnetization is the detrital one, appeared during sediment accumulation. The secondary viscous component is not stable and completely disappears under temperature of $200-300^oC$. The main paleomagnetic parameters of geomagnetic field excursions, revealed within Brunhes epoch, are given together in table 1. Fig. 1 shows their changes in time.

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Reversed and anomalous field directions are found out in Holocene deposits sections. They occupy narrow intervals in stratigraphic column and are characterized by low values of I_n and $\varkappa$. Ancient field (H_{an}), determined by resedimentation, appeared to be: for subzone N_1r_1 = 12.8 $A.m^{-1}$, for N_1an_1 = 13.6 $A.m^{-1}$, that is $\sim$1/3 of geomagnetic field intensity during stationary regime for Holocene period (for Holocene H_{an} = 0.55 oe or 44 A/m).

Two intervals with one reversed and the other one anomalous I_n were revealed in the sections of Upper-Quaternary deposits. The thickness is 0.15 and 0.30 m; they have some peculiarities, distinguishing them distinctly from one another and from neighbouring normal zones (table 1 and fig.1).

Because of the presence of stony material H_{an} for subzone N_1r_1 was not determined. Within subzone N_1an_2 H_{an} is 4.8 $A.M^{-1}$, that is 1/10 part of geomagnetic stationary regime intensity for the Late-Quaternary period, determined by resedimentation.

In the sections of Middle-Quaternary deposits one anomalous and one reversed interval of geomagnetic field were found. We marked them as N_1an_3 and N_1r_3 zones. Intensive variation of geomagnetic field directions is typical for N_1an_3 subzone, coupled with gradually decreasing of its intensity (fig.1). A complete reversal is typical for subzone N_1r_3. Large magnetic viscosity of samples in N_1r_3 zone did not allow to determine H_{an} by resedimentation.

Some significant differences in magnetic characteristics and in mineralogical composition of samples from normal and reversed zones as well as of anomalous zones, have not been observed. The revealed zones may be caused only by field behaviour in the period of these rocks formation and they are interpreted as geomagnetic field excursions. It is necessary to point out, that these geomagnetic field excursions, determined in the period of Zeraphshan Valley Quaternary deposits investigations, were in the sections of nearby territories.

Summing up the results of investigations it is possible to do the following conclusions:

1. Within anomalous (N_1an_1, N_1an_2, N_1an_3) and reversed intervals (N_1r_1, N_1r_2, N_1r_3) considerable decreasing of H_{an} is observed.
2. Geomagnetic field excursions have no predictions.
3. Revealed deviations of geomagnetic field may be used by the subdivision and correlation of quaternary deposits sections.

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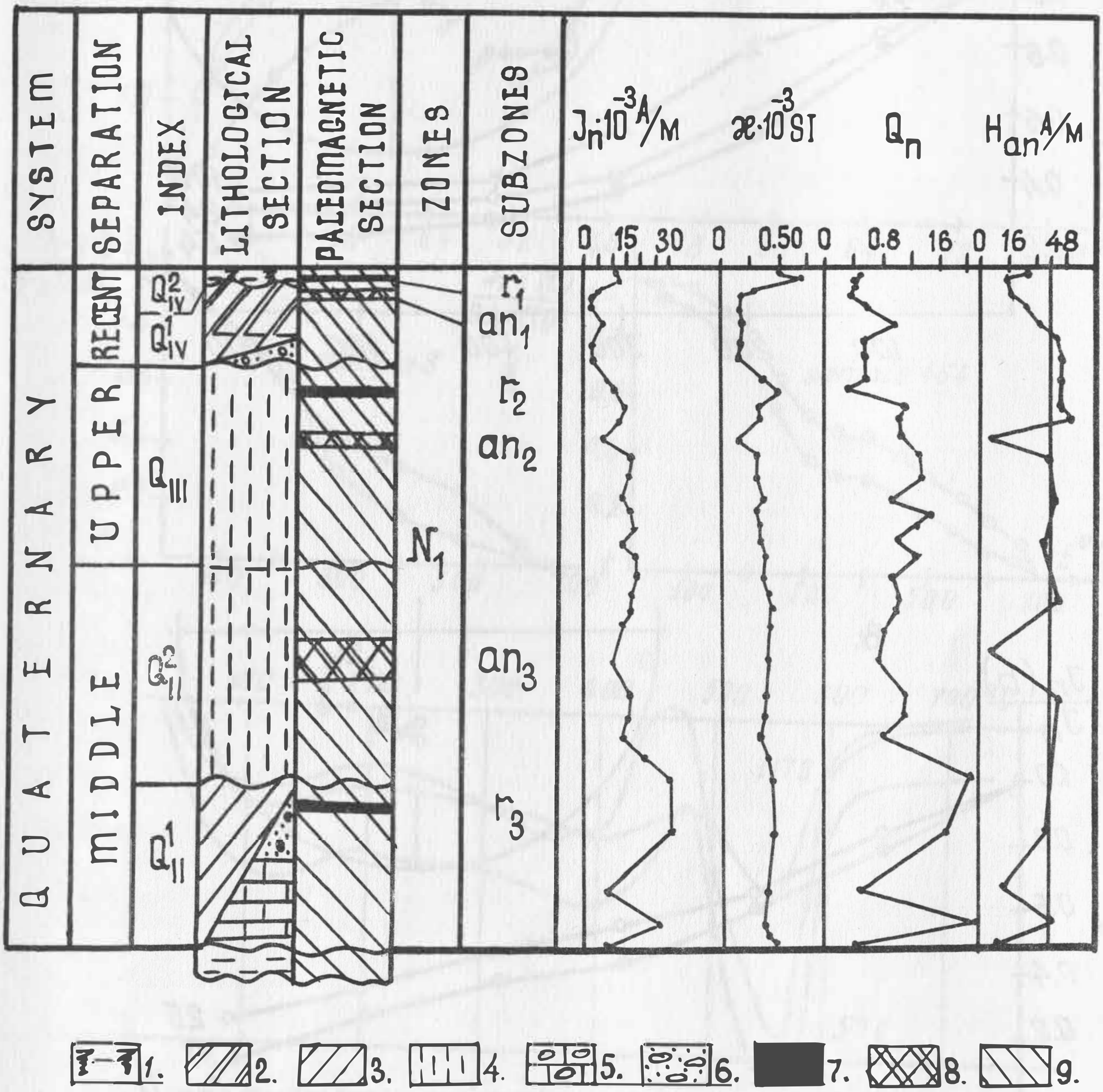

Fig. 1. Change of mean values of the main paleomagnetic parameters in Brunhes epoch.

1. Recent soil horizon.
2. Compact loam.
3. Loess-like loam.
4. Loess.
5. Conglomerate.
6. Coarse-graded material (gravel, sands, grit).
7. Zone of reversed magnetization
8. Anomal zone.
9. Zone of normal magnetization.

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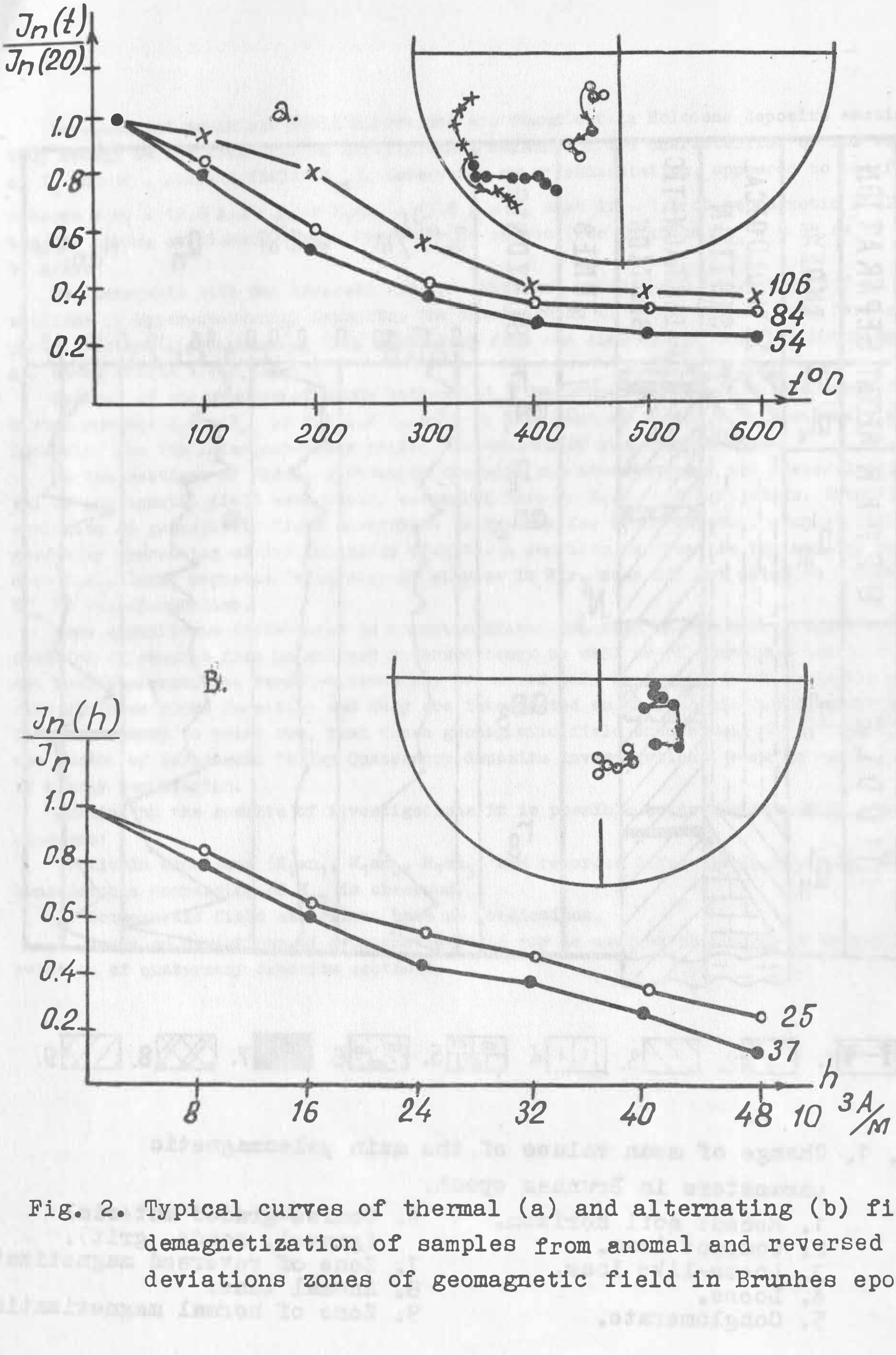

Fig. 2. Typical curves of thermal (a) and alternating (b) field demagnetization of samples from anomal and reversed deviations zones of geomagnetic field in Brunhes epoch.

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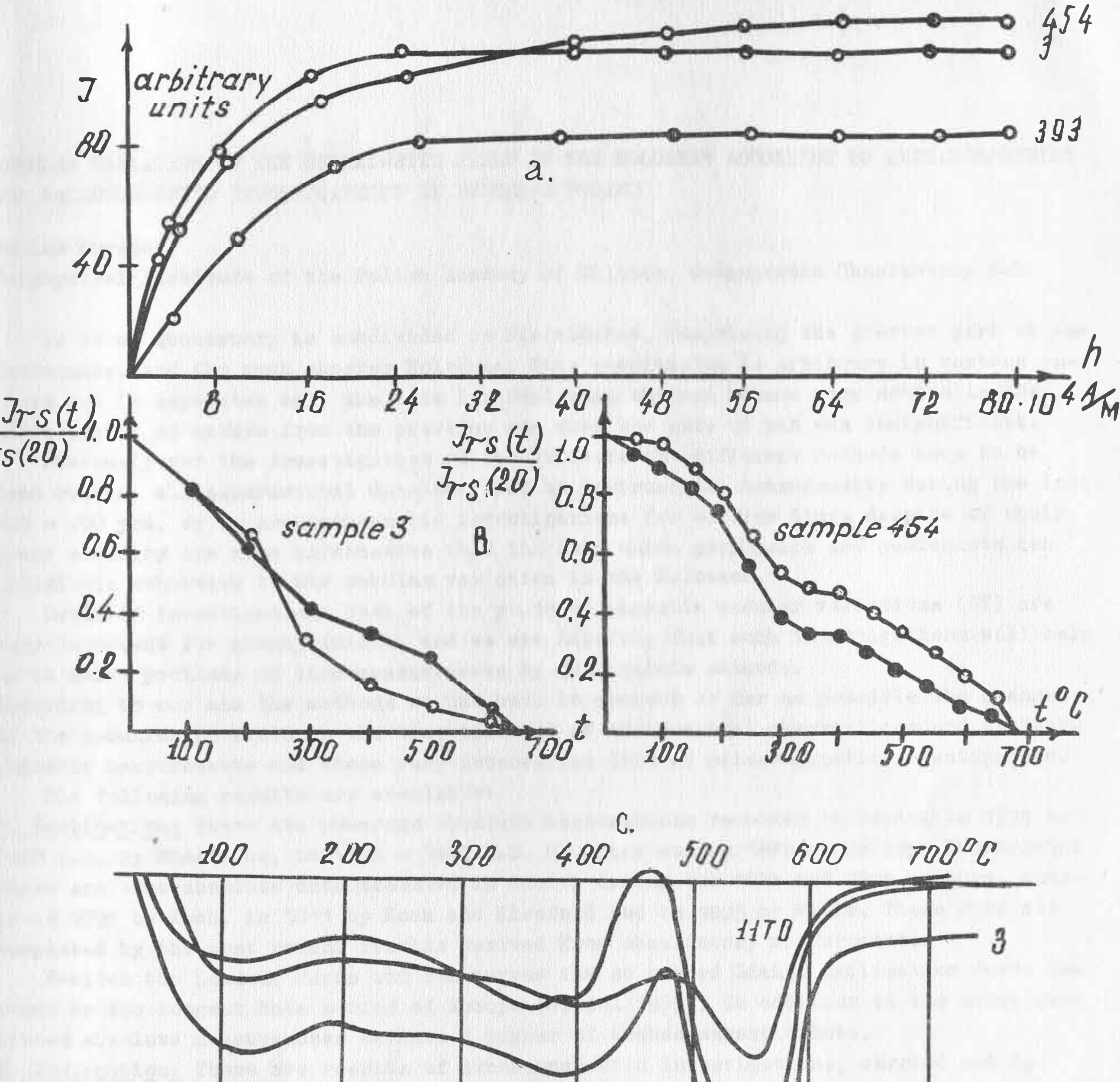

Fig. 3. Typical curves of:
a) isothermal magnetization,
b) thermomagnetic analysis
I - first heating
II- second heating,
c) TDMA (data by B.V.Burov).

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SECULAR VARIATION OF THE GEOMAGNETIC FIELD IN THE HOLOCENE ACCORDING TO ARCHAEOMAGNETIC AND PALAEOMAGNETIC INVESTIGATIONS IN NORTHERN POLAND

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As known Quaternary is subdivided in Pleistocene, comprizing the greater part of the Quaternary, and the much shorter Holocene. This subdivision is arbitrary in various aspects but it separates well the time interval when the man became more active in the assimilation of nature from the previous one when the role of man was insignificant.

Obviously for the investigation of the Holocene two different methods have to be used because all experimental data obtained by instrumental measurements during the last 400 - 200 yrs. or by archaeomagnetic investigations for earlier times despite of their lower accuracy are more informative than the data which geophysics and geologists can contribute otherwise to the secular variation in the Holocene.

Detailed investigations just of the youngest magnetic secular variations (SV) are very important for geophysicists, and we are hopeful, that such investigations will help us to solve problems of time measurements by geomagnetic methods.
According to our aim the methods we use have to connect as far as possible the changes of the geomagnetic field in the time interval of instrumental observations and archaeomagnetic measurements and those very interesting data of palaeomagnetic investigation.

The following results are available:
1. Declination: There are numerous absolute measurements recorded in Gdańsk in 1539 and 1540 A.D. by Rhaeticus, in 1628 - 1682 A.D. Hevelius and in 1679 by Halley. Furthermore there are some absolute data measured in Gdańsk during the 18th and 19th century, namely in 1795 by Koch, in 1811 by Koch and Kleefeld and in 1823 by Hille. These data are completed by the most recent results derived from observatory measurements.

Besides the London, Paris and Rom curves the so called Gdańsk declination curve belongs to the longest data series of Europe (Olczal 1955). In addition to the above mentioned absolute measurements we have a number of archaeomagnetic data.
2. Inclination: There are results of archaeomagnetic investigations, carried out by Zofia Csyszek (1977) for the time interval from 1065 A.D. to the present in intervals of 30 - 40 yrs. and furthermore there are some results of earlier times obtained by the archaeomagnetic method.
3. Declination and inclination: These data are taken from palaeomagnetic investigations of Creer and his colleagues (1979) obtained from bottom sediments of two lakes: Cherzykowskie (CH-6) and Zarnowieckie (ZR 3; ZR 6), both not far from Hel.

Presentation of results:
Using these data we succede to extend the time interval of geomagnetic secular variation series to some thousend years back to 5 500 yrs. B.P. for declination and back to 3 500 yrs. B.P. for inclination (fig. 1). It is noteworthing, that the archaeomagnetic results agree very well with palaeomagnetic curves, not only with declination but also with inclination curves.

The diagrams confirm the following periods in the variation of the direction of the geomagnetic field: for the declination 700, 1700 and 2 700 yrs. and for inclination 400 and 1 000 yrs. Applying our analysis we recieved the following periods for the geomagnetic field intensity (Czyscek 1977): 11 200, 1 200, 360 and 160 yrs.
On the basis of all these data for Poland (Gdańsk - Hel) it is possible to estimate SV

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periods for declination and inclination from 5 500 and 3 500 yrs. B.P. respectively up to the present. It has to be emphasized that these data are relative minimum values.

Data series for a longer time interval could only be recieved after a further development of the archaeomagnetic method. The maxima and minima positions in the investigated time interval for Gdańsk - Hel (54,4° - 54,6° N) are:

declination	yrs. B.P.	inclination	yrs. B.P.
A (-)	177	a (-)	210
B (+)	598	b (+)	400
C (-)	783	c (-)	625
D (+)	1 380	d (+)	800
E (-)	2 410	e (-)	1 020
F (+)	3 250	f (+)	1 650
G (-)	4 950	g (-)	2 120
H (+)	6 100	h (+)	2 600

maximum (+), minimum (-).

The master curves of declination for England and for Hel coincide very well. However the comparison with the results of Kovacheva (1982) shows, that the variation patterns of Bulgaria differ from those of Poland (fig. 2). A comparison of the periods obtained by the analysis of Bulgarian and Ukrainian data does'nt show any agreement. So it is left to suppose, that secular variation is not a global phenomenon but a regional one which isn't obviously connected with the global geomagnetic field.

The results described here can be used as starting-point for further investigations. Our results show that even a so limited initial data material as we used in this paper allows to get a general idea about the secular variation of geomagnetic elements in the region being interesting for us.

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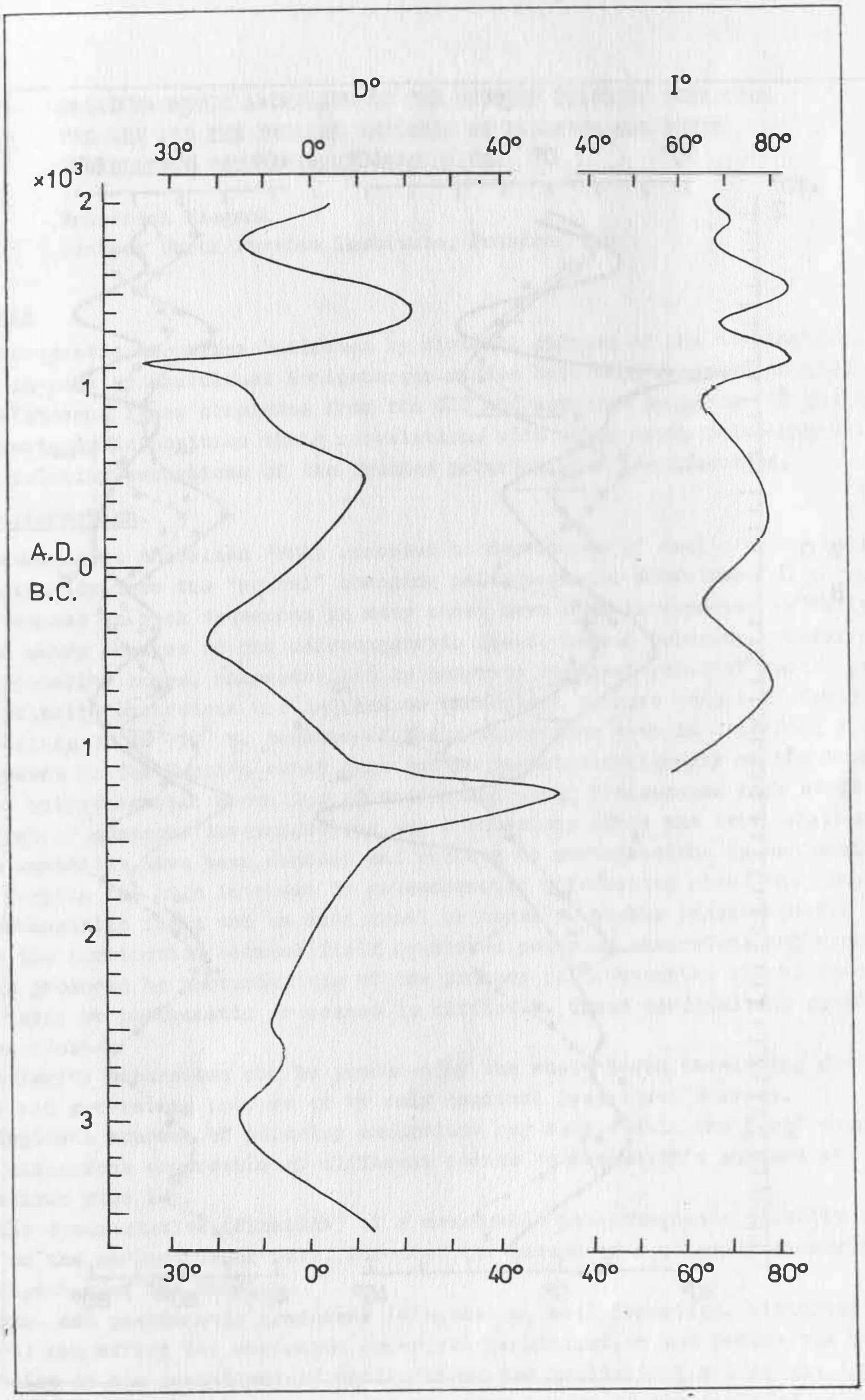

Fig. 1. Variation of inclination and declination in Gdańsk-Hel (Poland) for the last 5 000 yrs.

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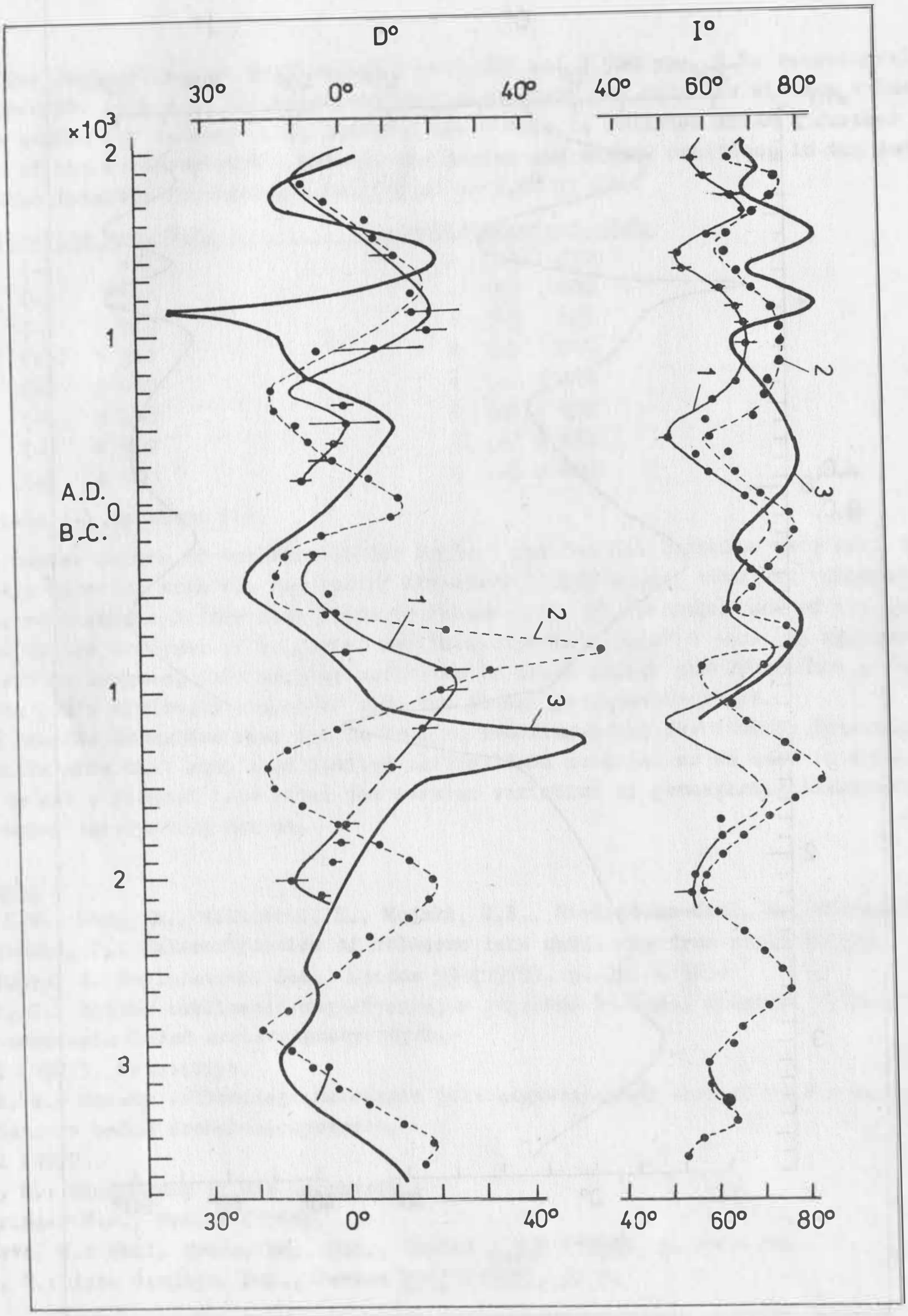

Fig. 2. Secular variation of inclination and declination in Bulgaria (1), Ukraine (2), and Poland (3) for the last 5 000 yrs.

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PALAEOMAGNETIC ANOMALIES OF THE BRUNHES POLARITY ZONE FROM THE GDR AND THE PEOPLES REPUBLIC OF BULGARIA AND THEIR CORRELATION WITH POLARITY EXCURSIONS

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Summary

Palaeomagnetic anomalies indicated by distinct changes of the declination, inclination and in part by diminished Königsberger ratios have been recorded in middle and upper Pleistocene loess complexes from the GDR and northern Bulgaria. On the base of their stratigraphic position their correlations with other known palaeomagnetic anomalies and polarity excursions of the Brunhes polarity zone are discussed.

1. Introduction.

Palaeomagnetic anomalies (PMA) recorded as departures of declination, inclination and/or intensity from the "normal" changing palaeomagnetic behaviour (of the palaeomagnetic elements) in rock sequences in many cases have been interpreted as reflections of short and sharp changes of the palaeomagnetic field, termed polarity excursions. In contrast to polarity zones, characterized by complete reversed polarity during periods of $>10^4$ y. polarity excursions are defined as incomplete changes (angle of deviation $<180^\circ$) within periods of 10^3-10^4 y. Because of their importance both in modelling field generating processes in the Earth's outer core and to magnetostratigraphy of the Brunhes polarity zone palaeomagnetic anomalies of middle and upper Pleistocene rock series have been the subject of numerous investigations and discussions since the late sixties. Many of reported anomalies have been doubted and reduced to perturbations by sedimentary processes. Despite the high interest in paleomagnetic information about the fine structure of the geomagnetic field and in additional criteria of higher palaeomagnetic time resolution the distinction between field generated polarity excursions and geomagnetic anomalies produced by perturbations of the primary palaeomagnetic signal in consequence of syngenetic or postgenetic processes is difficult. These difficulties results from the following causes:

1. Polarity excursions can be produced by the whole Earth enveloping disturbances of the field generating process or by only regional restricted sources.
2. Regional sources of polarity excursions may move within the fluid outer core causing excursions observable at different points on the Earth's surface with a more or less distinct time lag.
3. The documentation (fixation) of a measurable palaeomagnetic polarity excursion depends on the sedimentation rate. Moreover the record of a polarity excursion depends on the distance of the samples.
4. Syn- and postgenetic processes (diagenesis, soil formation, bioturbation, kryoturbation) can affect the excursion generated magnetization and reduce the primary characteristics of the deviations of declination, the inclination and/or the intensity.
5. For dating the time position and the correlation of the recorded polarity excursions hitherto only a few dating methods with low ranges and low precision (^{14}C, TL, ESR, depositional rate) are available.

Polarity excursions are to be seen as distinct secular variations of the palaeomagnetic field, from which they differ only in amplitude. In contrast to true field re-

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versals with reduced field intensities up to 10 per cent of the stationary field polarity excursions are not necessarily accompanied by decrease of the field intensity.

2. Methods and criteria for the identification of palaeomagnetic anomalies and polarity excursions

During the palaeomagnetic investigations of continental deposits of the middle and upper Pleistocene of the GDR and Bulgaria several palaeomagnetic anomalies have been recorded, some of which can be regarded as true polarity excursion equivalents by the sum of the following criteria:

1. Deviation of the declination of more than 90°, of the inclination of more than 60° from the normally changing palaeomagnetic record of the treated rock sequence.
2. Indication of the anomaly by at least 3 samples.
3. Confirmation of the recordes anomaly at parallel sections.
4. Exclusion of syn- or postgenetic perturbations of the primary depositional remanence in consequence of weathering, soil forming processes, kryo- or bioturbations.

For the identification and characterizing of the anomalies as regional or global phenomena their dating is of fundamental importance. On the base of the correlation of the central and southeastern European climatostratigraphic schemes with the well dated global marine oxygen isotope scale (OIS) calibrated by the magnetostratigraphic Matuyama/Brunhes reversal it was possible to asses the age of the anomalies within boundaries of 10^4 y. To determine the palaeomagnetic characteristics of the investigated sections sampling and cleaning methods have been applicated as described by Wiegank (1977). Moreover to identify the remanence carrying minerals optical, röntgen-phase-analytical and thermoremanent treatments have been carried out.

3. Characteristics of palaeomagnetic anomalies of the Brunhes polarity zone from the GDR

3.1. Loess soil complex of Rittmitz. In the dolomite quarry of Rittmitz near Leipzig an up to 15 m thick loess sequence with 3 intercalated fossil soils is exposed. According to bio-, pedo- and morphostratigraphic criteria the loess complex of Rittmitz represents the standard section for the middle to upper Pleistocene of Saxony of the GDR. The Lommatzsch, Altenburg and Rittmitz soil are true interglacial pseudogleys, correlated with the Eemian, Rügen and Treene interglacial respectively according to the regional stratigraphic scheme of the GDR. Because the Holsteinian interglacial has been U/Th-dated to 350000 y and the next younger Wacken-Dömnitz interglacial to 326000 y (Stremme, 1983) these interglacials have to be correlated with OIS 11 and 9 according to the time scale of Morley, Hays (1981). Because the typical Lommatzsch soil correlated with the Eemian and the Rittmitz soil is underlain by loess of the Saalian glaciation both the Rittmitz and the Altenburg soils are formed during the OIS 7 which in accordance with these findings exhibits in several deep sea cores two ^{18}O minima separated by a clear deep minimum. Thus the Rittmitz soil is dated to be older than 244000 y and the Altenburg soil is younger than 188000 y.

The behaviour of the declination and inclination changes during a.f. cleaning indicates that VRM has been destroyed after demagnetization by 20 mT. The variations of D and I within the prepondorate part of the section are small. But both the basal part of the Rittmitz soil and the uppermost part of the Lommatzsch soil including the base of the overlain loess cover are characterized by strong changes of D, I, I_n and remarcable variations of the Königsberger ratio Q. This findings have been confirmed by one parallel section with overlapping samples. Lithological changes within these parts of

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section are not observable. Contrasting to the distinct palaeomagnetic variations in the levels of the Rittmitz and the Lommatzsch soils the range of the Altenburg soil shows no extraordinary changes of the palaeomagnetic field. Within the lower Rittmitz anomaly (1) the declination changes two times from about 0° to 180° reflected in changes of the inclination from about $+60^{\circ}$ to $+30^{\circ}$ and about $+60^{\circ}$ to -60°. Parallel to this variations field intensity is diminished to about 0,5 as indicated by the Königsberger ratio. As the lower anomaly the upper anomaly (2) of the Rittmitz section is characterized by declination changes from about 0° to 180° and inclination changes from about $+60^{\circ}$ to -60° and around $+20^{\circ}$ respectively. The field intensity diminishes as in the lower anomaly before the commencement of the sharp directional variations of the geomagnetic vector and drops nearly to zero. According to these characteristics the palaeomagnetic anomalies of the Rittmitz section are to be seen as caused by true changes of the palaeomagnetic field. Their stratigraphic positions within the well investigated Rittmitz loess complex allows to assess their commencements by means of their distances to soils to about 250000 y and about 110000 y respectively. The true dating depends on the model of the time relation between loess sedimentation and soil forming processes. Generally loess sedimentation is time correlated with glacials or cold period, soil formation with interglacials or warm periods. If loess sedimentation is interrupted during a warm period than the upper level of a soil dates the end of a cold period, all levels beneath the soil surface than are older according to the rate of deposition. A second model is also possible. Under semiarid to arid conditions with the beginning of an interglacial loess sedimentation and soil formation can superpose so that the lower edge of a soil may mark the beginning of that interglacial warm period. In the first case the Rittmitz (1) anomaly would be older than the Rittmitz soil and the beginning of the OIS 7 (may be some ten thousands of years). The Rittmitz (2) anomaly in this case has to be dated to the end of the OIS 5e (115000 y). In the latter case the Rittmitz (1) anomaly has to be dated some thousands of years younger than the beginning of OIS 7, may be about 230000 y, but the date of the Rittmitz anomaly does not change. A third possibility of timing of the remanence forming processes under the influence of soil formation has to be taken into account. Weathering and pedogenesis may produce a chemoremanent magnetization by solution and recrystallization in the lower illuvial horizons of soils during the maximum of an interglacial period. Indications of such processes are maxima of NRM and of the susceptibility as recorded in the Kosar Belene section. Such characteristics are significant for palaeosoils of middle to lower latitudes. Because these indications are not remarkable in the Rittmitz section and besides this the likelihood of loess sedimentation under moderate to warm humid climatic conditions is very small we prefer to accept the first dating model for the middle European middle to upper Pleistocene. Thus the commencement of the Rittmitz (1) anomaly has to be dated before the beginning of OIS 7, to the late Saalian glaciation. From this time other polarity excursions have been reported (Eastern Europe, Italy, Middle Asia) which may be due to the same field disturbing source in the outer core. Other indications of a time equivalent polarity excursion has been recorded in glacilimnic deposits of Profen near Leipzig, overlain by till of the Saalian I cold period correlating with OIS 8. This level can be dated to about 270000 y. Whether all these excursions are correlated also with numerous other anomalies dated by different methods around 300000 y cannot be decided to day. Because the Lommatzsch soil is correlated with the well.dated last interglacial (Eemian, OIS 5e), 128000 to 115000 y) the Rittmitz (2) anomaly can be dated to 110000 y, the age of the well known Blake event (better the Blake polarity subzone). This time correlation and

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the paleomagnetic characteristic of real field reversal confirm the identity of the Rittmitz (2) anomaly with the Blake polarity subzone.

3.2. Mahlis clay pit. In the Mahlis clay pit northwest of Dresden a 10 m thick loess complex with 3 intercalated fossil soils is exposed overlain by tills of the Elsterian and Saalin glaciations. The fossil soils are interglacial pseudogleys. According to Fuhrmann et al. (1977) the palaeomagnetic variations within the basal cold period mud between reversed and normal polarity has to be interpreted as the transition from the Matuyama to the Brunhes polarity zone. Besides this transition zone in the range between loess 3 and the soil 3 (Ma γ) strong changes of the declination (0° to 270°) and of the inclination ($+60^{\circ}$ to -60°) indicate a distinct palaeomagnetic anomaly (Wiegank, 1977). According to new results these variations are accompanied by a diminishing of intensity. There are no indications of variations in sedimentation. The loess complex of Mahlis comprises the Cromerian of the Brunhes polarity zone. The range and correlation of the Cromerian complex with the OIS has been disputed up to now, because the radiometric age of the stratigraphic important Holsteinian interglacial and its correlation with the OIS was not known. Now U/Th dating of the type marine Holsteinian deposits with ages between 326000 to 350000 y (Stremme, 1983) has proofed the correlation of the Holsteinian interglacial with OIS 11 as proposed former by Wiegank (1977). Thus the Cromerian of the Brunhes polarity zone has to be correlated with the OIS 19 to 13, that means that during the Cromerian of the Brunhes polarity zone a fourfold change from cold to warm climatic conditions took place. This contrasts with the findings of only three climatic changes documented in the loess soil complex of Mahlis. This discrepancy is also evident from other continental regions as, e.g. SE Europe and Middle Asia. This deviation may be caused by differences in the intensities of cold and warm periods, by reduction of loess sedimentation during the more moderate cold periods of the Cromerian. In this case a superposition of soil formation may pretend the loess of full climatostratigraphic findings equivalent to the OIS. Thus within the section of Mahlis the thick lower pseudogley (Ma α) is interpreted to represent the OIS 19 to 17, because OIS 18 exhibits only moderate climatic depressions. Then the palaeomagnetic anomaly at the level of the loess 3 soil boundary correlates with the OIS 14/13 dated around 500000 y. Comparable with this deviation is a fluctuation of the declination and the inclination of about 90° and 40° respectively in the "Lehmschichten" of the famous mammal finding place of Voigtstedt, Thuringia. Moreover there are some other records of palaeomagnetic anomalies at this time level (about 475000 y) from marine and continental sediments as well, reported from SE Europe, Middle Asia, Siberia, Caribean and Pacific. So the Zavadovka soil anomaly reported from Pospelova, Gnibidenko (1982) and the soil VIII anomalies of Middle Asia (Dodonov, Pen'kov, 1977) are situated within the same climatostratigraphic position as the Mahlis anomaly, which all obviously reflect a real field excursion.

4. Characteristics of palaeomagnetic anomalies of the Brunhes polarity zone from the northern Bulgarian loess province

4.1. Clay pits of Russe and Silistra. In the middle to upper Pleistocene loess complex of these sections a palaeomagnetic anomaly was recorded between the palaeosoils FB$_3$ and FB$_2$ which correspond to the Eemian OIS 5e and the first Weichselian interstade 5c respectively. Thus these anomalies are comparable with the Blake polarity subzone (Wiegank, 1977). It is marked by distict changes of the declination (up to 180°) and of the inclination ($+60^{\circ}$ to -50°) whereas according to new results the diminishing of the field intensity indicated by Q ratio is remarkable but not sharp.

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4.2. The Kosar Belene Exposure. Near Kosar Belene at the highway to Russe a 18 m section of the north Bulgarian loess complex with 6 intercalated fossil soil horizons is exposed. Because the Matuyama/Brunhes boundary was not recorded the whole sequence is younger than 730000 y. In the section 5 palaeomagnetic anomalies have been recorded. The anomaly Kosar Belene (1) is situated within the lower part of the palaeosoil FB_6. It shows strong changes in declination and inclination and the field intensity is little diminished. Anomaly Kosar Belene (2) at the base of the FB_5 soil is characterized by two peaks in declination and inclination and a distinct decrease of the intensity. In the lower part of the FB_3 soil a sharp change of declination and decrease of inclination by about 120^o without significant decrease in field intensity marks a third palaeomagnetic anomaly. A fourth anomaly in the loess horizon L_3 between soils FB_3 and FB_2 is marked by small changes of the declination and stronger variations of the inclination and by a remarkable drop in palaeofield intensity. The uppermost anomaly shows distinct changes in declination and inclination without significant diminishing if the intensity. Other remarkable characteristics of the whole section are considerable variations of the NRM correlated with changes of the susceptibility and the intensity of soil formation. Because of the rarity of biostratigraphic findings and other stratigraphic criterions the loess stratigraphic conception of northern Bulgaria is in discussion up to now (Fotakieva 1982; Nozharov et al., this monography). In general the soil FB_5 is seen as time equivalent with the Mindelian/Rissian (Holsteinian) interglacial. Comparing the loess-soils sequence of northern Bulgaria with the global palaeoclimatic development as documented by oxygen isotope Variation the soils FB_6 to FB_3 are correlated best with the OIS sequence 15 to 5e (FB_6 correlates with OIS 15 to 13, FB_5 correlates with OIS 11 to 9, FB_4 with OIS 7, FB_3 with OIS 5e). On this base the recorded anomalies can be dated as follows:

Kosar Belene 1 - OIS 16 to 15 - about 575000 y.
Kosar Belene 2 - OIS 12 to 11 - about 425000 y.
Kosar Belene 3 - OIS 5e - about 125000 y.
Kosar Belene 4 - OIS 5d - about 110000 y.
Kosar Belene 5 - OIS 4 - about 45000 y.

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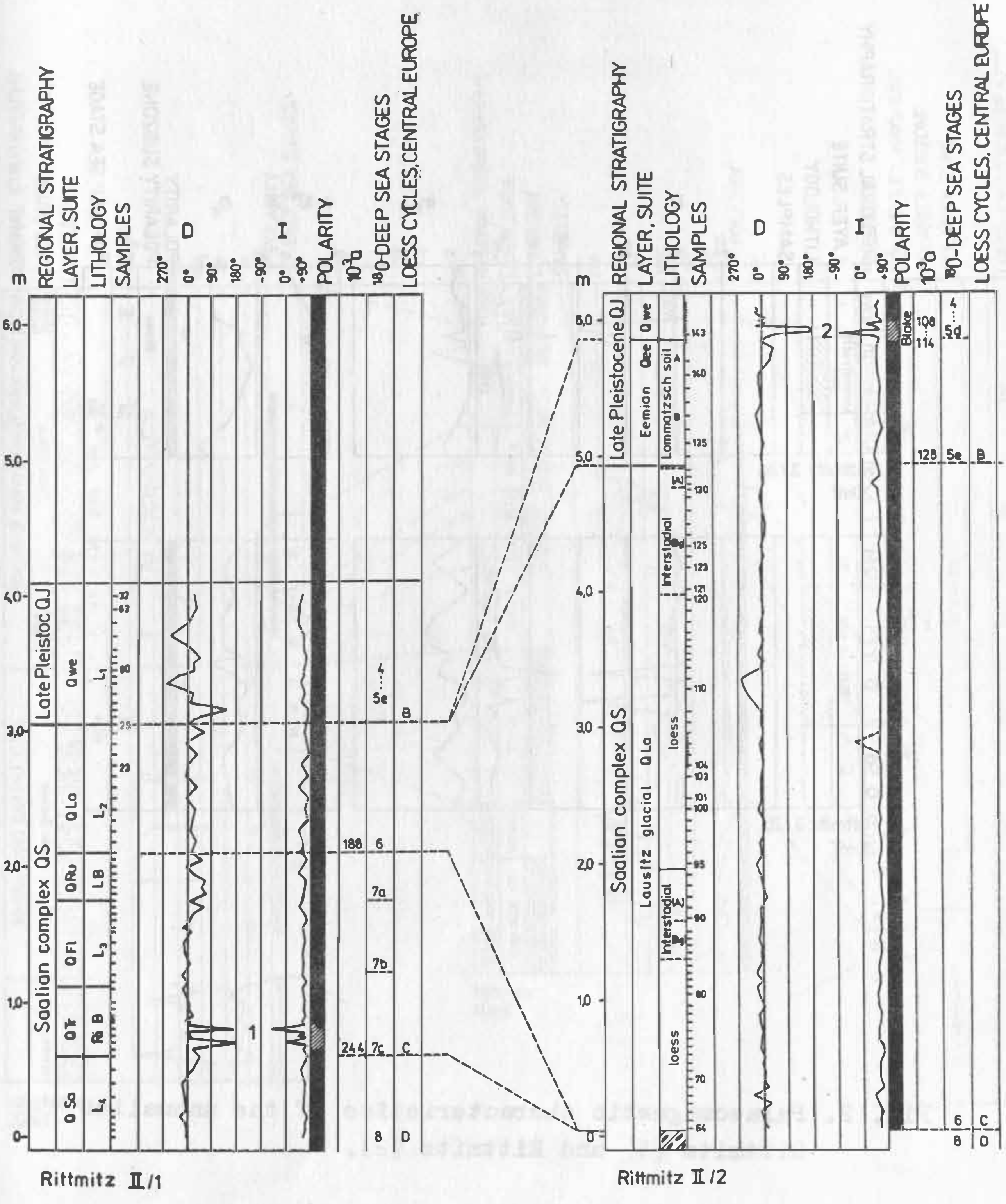

Fig. 1. Palaeomagnetic characteristics of the section of Rittmitz

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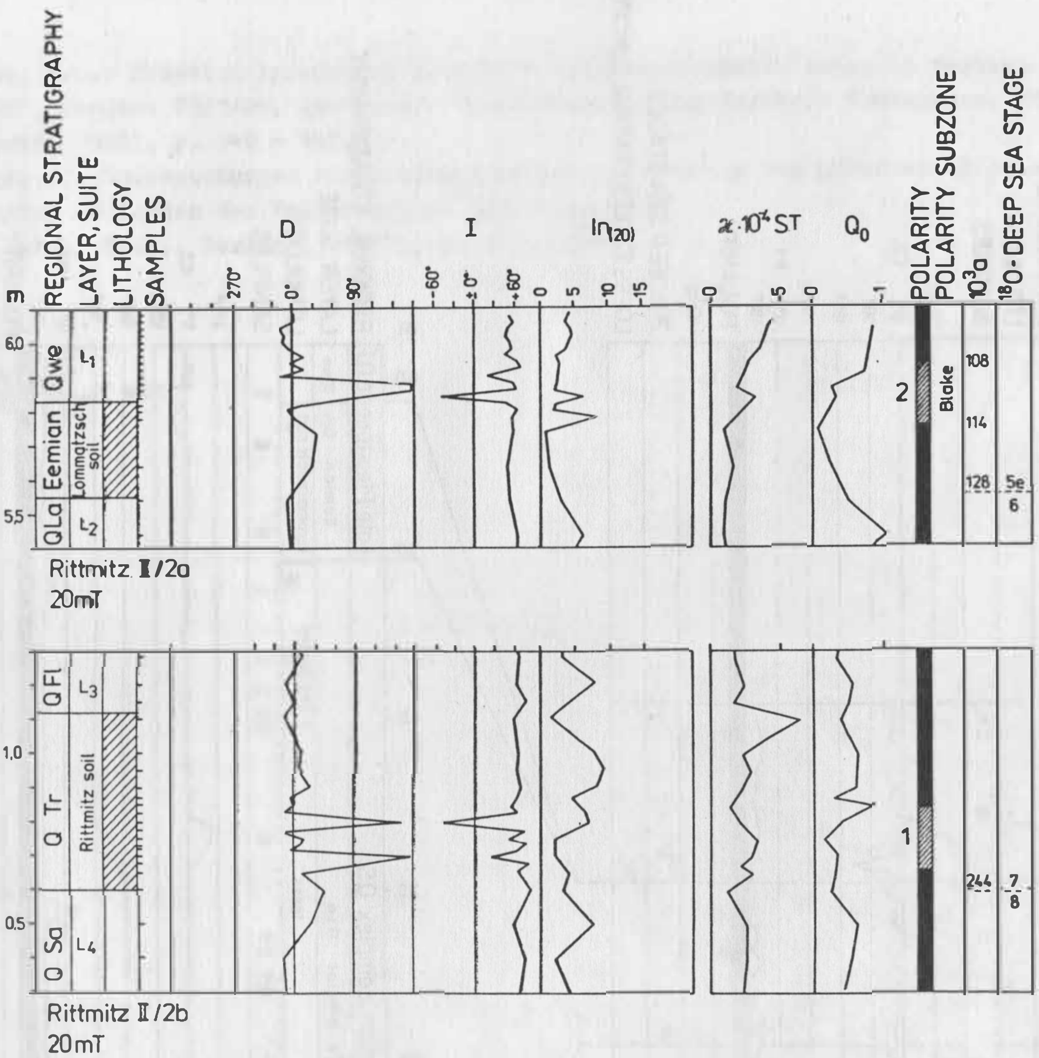

Fig. 2. Palaeomagnetic characteristics of the anomalies Rittmitz (1) and Rittmitz (2).

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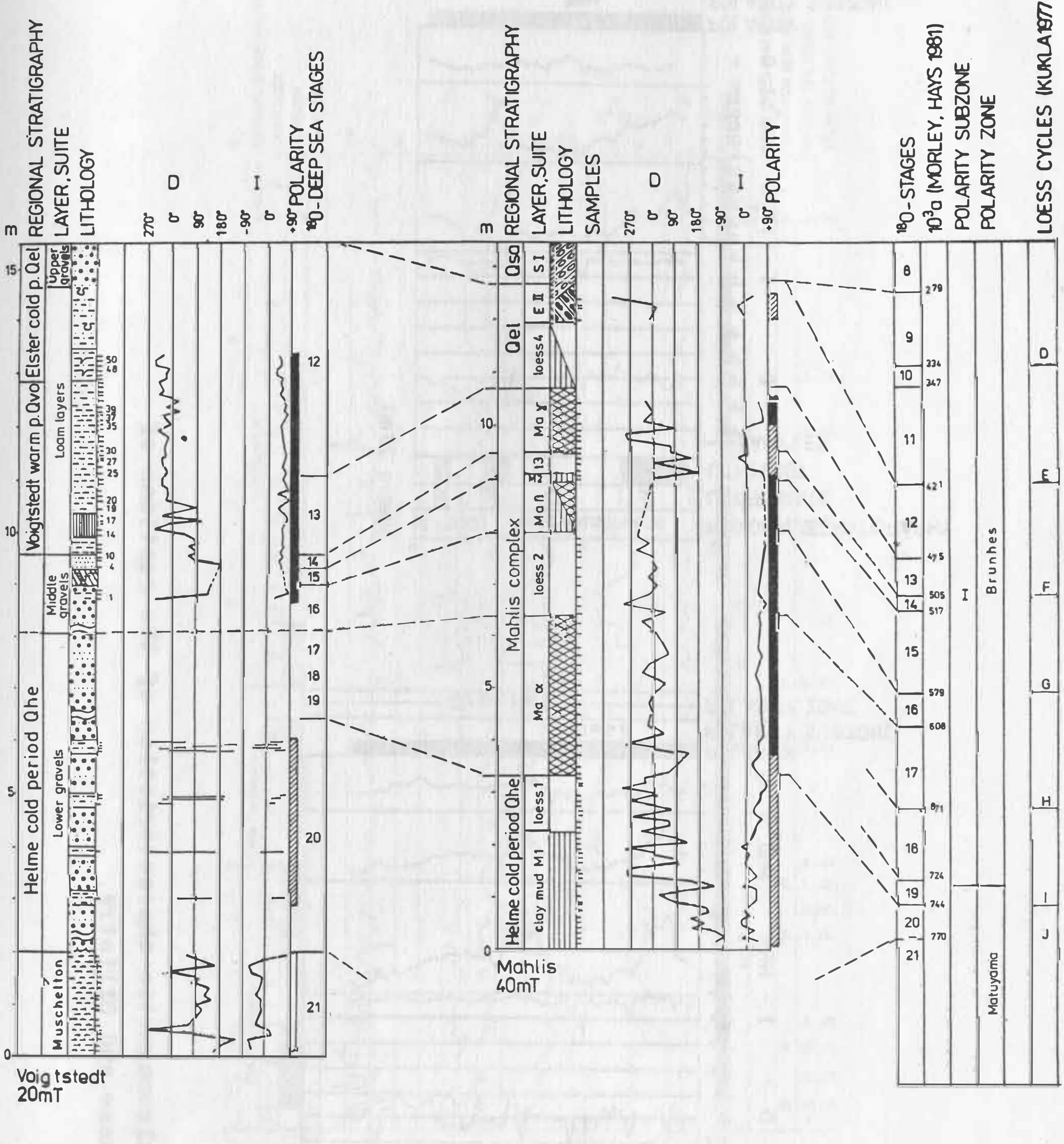

Fig. 3. Correlation of the sections of Mahlis and Voigtstedt on the base of biostratigraphic and magnetostratigraphic indications.

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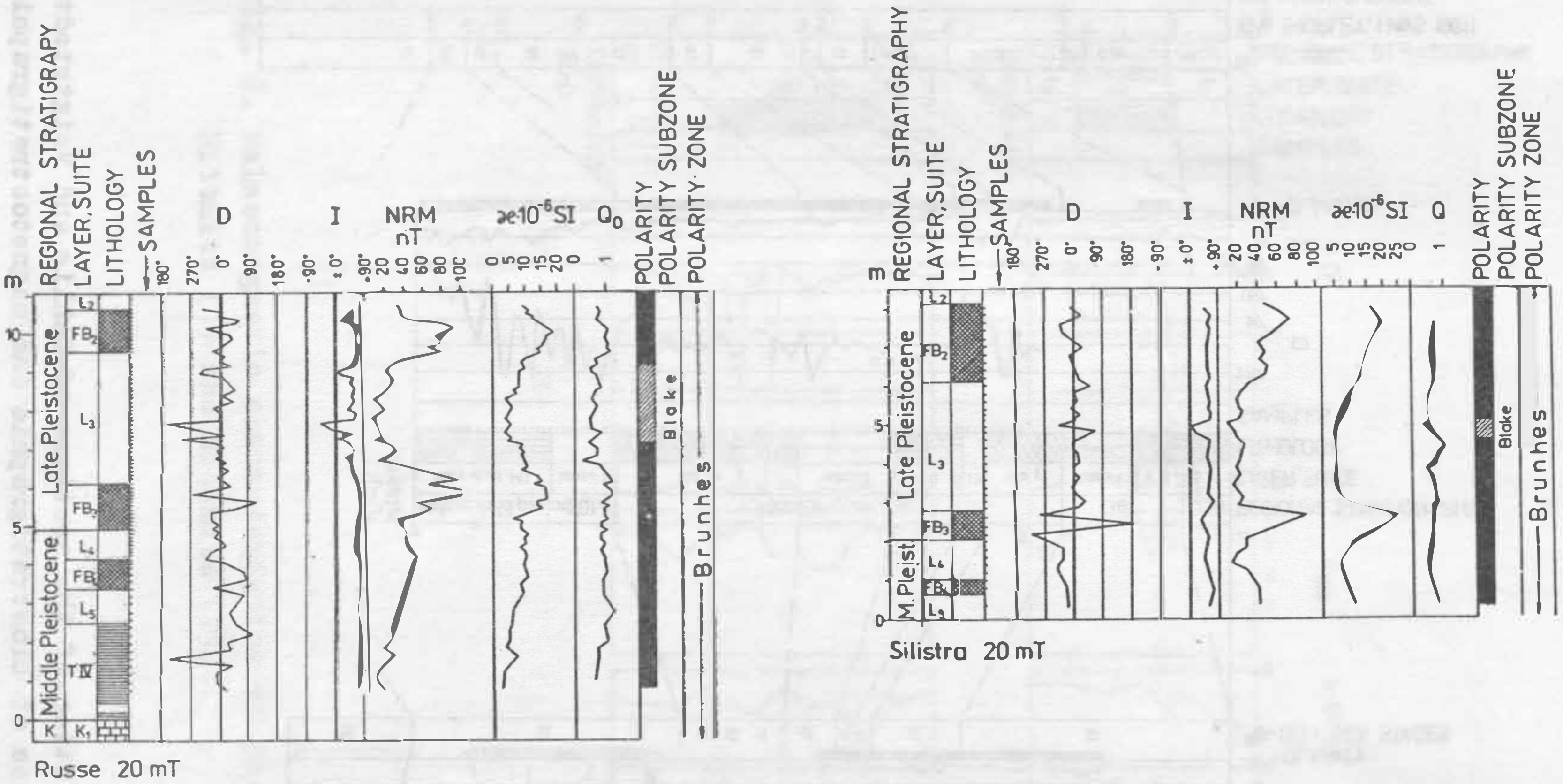

Fig. 4. Paleomagnetic characteristics of the sections of Russe and Silistra.

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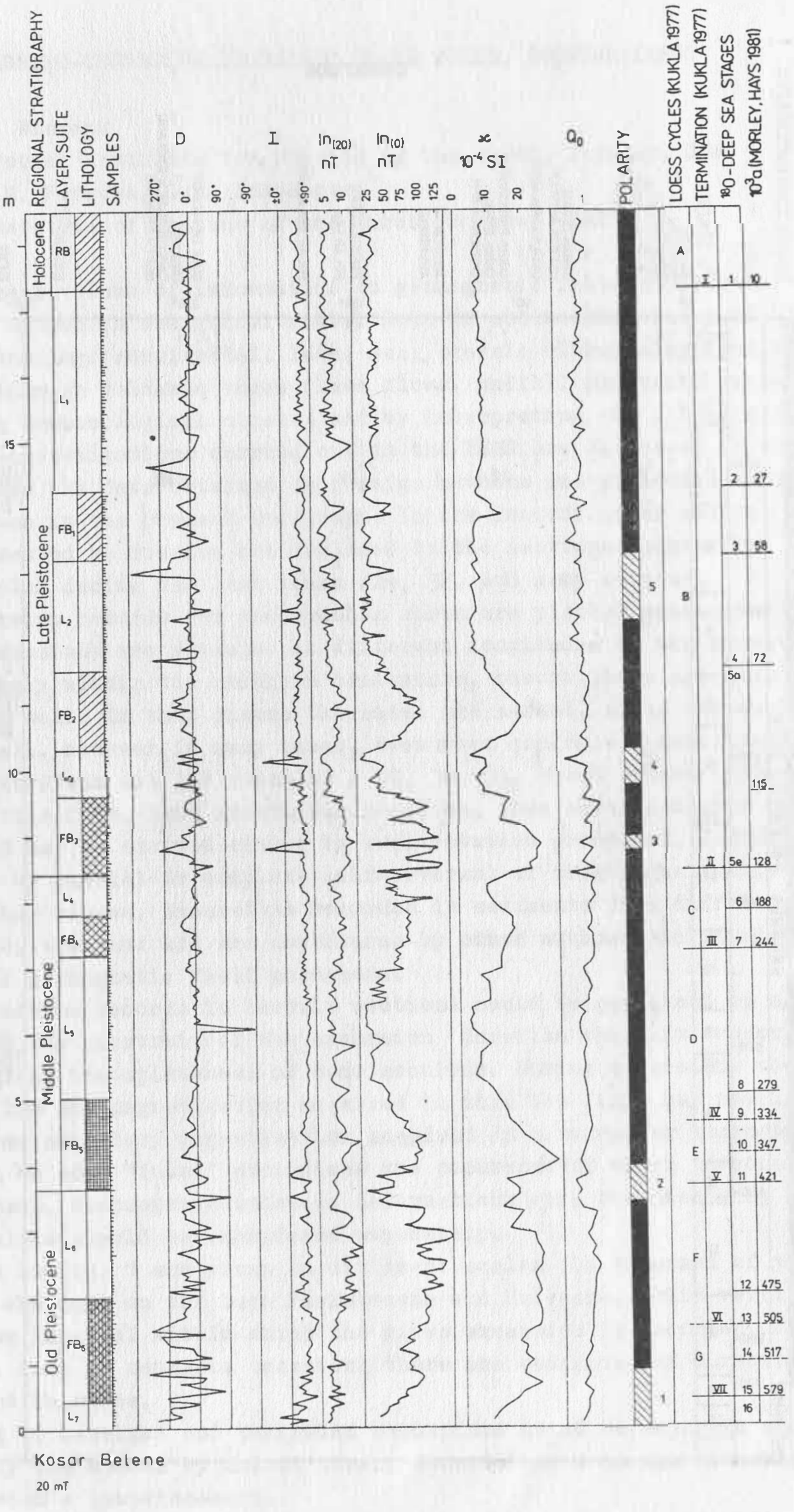

Fig. 5. Palaeomagnetic characteristics of the section of Kosar Belene.

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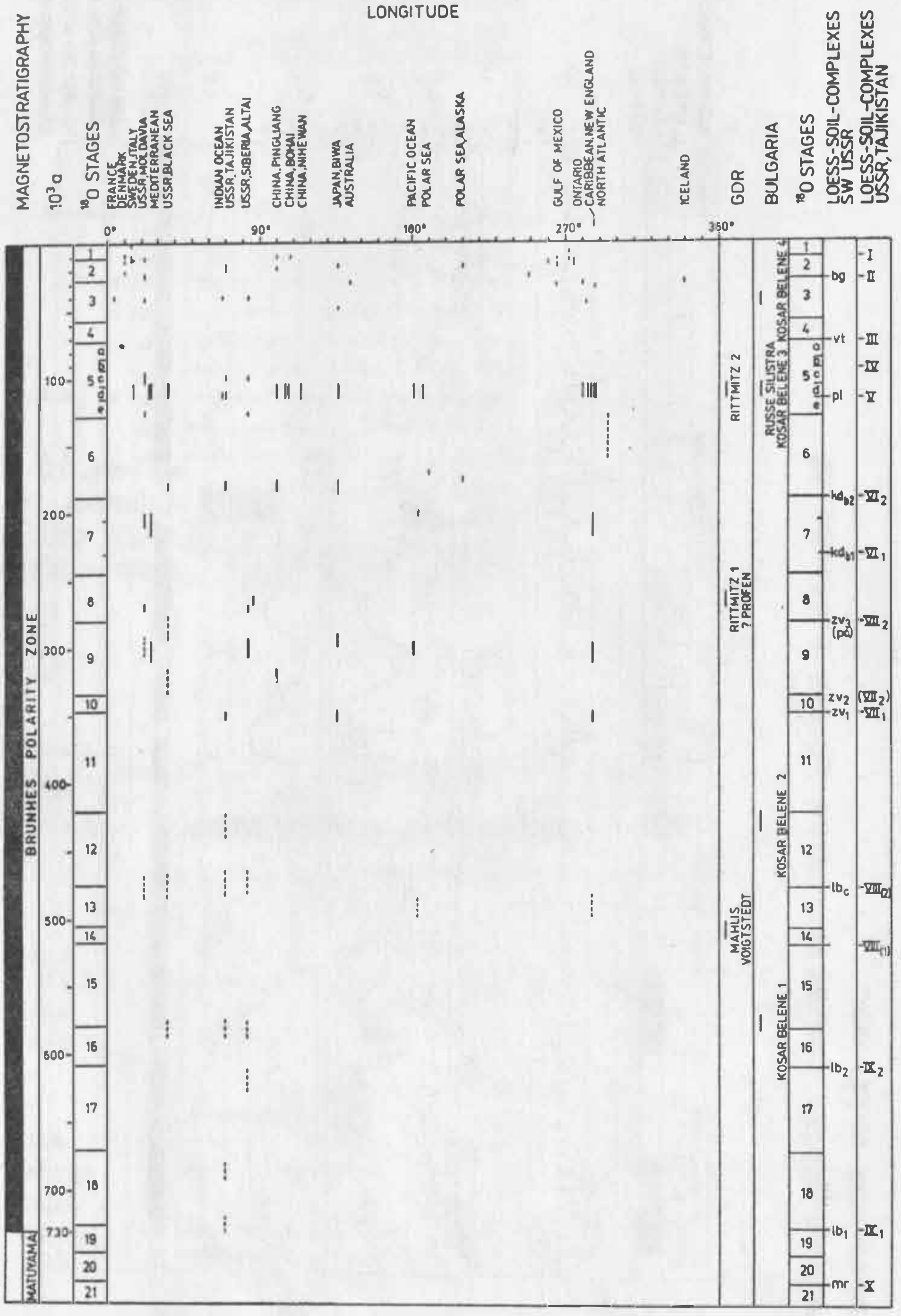

Fig. 6. Geographic and time distribution of palaeomagnetic anomalies of the Brunhes polarity zone.

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MAGNETO-CHRONOSTRATIGRAPHIC SCALE MODEL, BRUNHES CHRON

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At present a great volume of information on geomagnetic field excursions referring to Quaternary time is stored in the global scale. Data on sedimentary rocks of different genesis are predominating: continental, lake, sea, oceanic ribbon clays and even cave sediments, more seldom on volcanic rocks (lava flows, tuffs). Excursion records are also revealed using archaeological objects and by interpreting the linear geomagnetic sea anomalies. The investigations carried out in the USSR are discussed in detail in Pospelova's paper, while the data obtained by foreign authors are presented in Wiegank's paper; both papers are given in the present monograph. In the present paper all the data are generalized and supplemented by results not included in the mentioned summaries, as they are obtained in particular during the last years /24, 32, and many others/.

In fig. 1+) excursion records for the Brunhes chron are plotted against site longitudes. As can be seen, excursions are revealed at different longitudes of the western and eastern hemispheres but mainly within the northern hemisphere, though there are some data within the southern one as well. In this figure the sites are marked, where the excursions are settled reliably well, however in many cases, even when geological sections are explored in details, the excursions are not revealed / 20, 30, 31, 9 and others/. There is no unisonous opinion on this fact. Some scientists conclude, that excursions are not pure geomagnetic events and may be excited either by sedimentation processes, bioturbation and deformation /29/, or by partial or complete self-reversal of rock magnetization /18/. as well as by some other causes. Excursions recorded in sediments from different regions and facies and supposing the same age are considered by other authors including those of this paper as to be real geomagnetic field phenomena.

Absence of excursion records in certain sections could be explained by several causes. Taking into account the shortness of the excursion duration the main reason should be connected with certain incompleteness of some sections. During excursions the field intensity is rather low and magnetization acquired in this low field may remain unnoticed on a background of some secondary magnetization acquired in a normal or stronger fields. Of course there could be some "false" excursions the occurence of which is connected with sedimentation processes, technogenic sources, deformations etc. The discovery and exploration of such anomalies should be considered seperately.

The time marks in fig. 1 are given on different scales (in thousand of years) for better representation of the data on the Late Pleistocene and Holocene. Solid vertical lines correspond to the time interval within which the given excursion is recorded, but not to the interval duration. Only in separate occasions there are estimates of durations mainly based on sedimentation rates.

Data referring to moraines and suggested excursions based on separate sections and limited sample quantity are shown by dotted lines. Uncertainties in age determination are signed by arrows with a question-mark.

Naturally excursions revealed at different latitudes but at the same longitude could be given in fig. 1 only partially. Such cases are marked by a star. All the data in fig. 1 are properly weighted and analysed. The weights are aimed to account for relia-

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+) see supplement

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bility of excursion existence and the dating. Histograms of the frequency of excursion occurences are compiled for the last 150,000 yrs. Some of these histograms are similar to that compiled using the Soviet investigation data.

Two maxima can be seen on the global histograms plotted by using reliably dated excursions in the time-interval of 23 - 30 thousand years: one of them falls within 23 - 25 and the other within 27 - 30 thousand years (fig. 2).

To define the quantity of the excursions during the time-intervall of 150 -730 thousand years - the intervall in which accurately dated excursions are scarce - regional and interregional comparisons have been carried out on the quantity and reliability (thickness) of excursion records within the most complete sections containing several excursions.

The analysis and generalization of the more reliable data allowed to compile a model of palaeomagnetic and magneto-chronostratigraphic scale of the Brunhes chron; in future this scale should be improved, corrected and supplemented. The model is rather close to that previously compiled in /13, 15/ but yields some distinctions.

The excursions have been named according to the historical priority and mentioning in the literature references, though excursions are global phenomena and some of them have been investigated later more in detail.

on the basis of the mentioned criterions the following excursions can be distinguished (fig. 1):

1. Etrussia excursion dated from 2 700 - 2 800 yrs. B.P. was recorded in the USSR using archaeological objects of Georgia /10/, sedimentary rocks of the Predurals, bottom sediments of the White Sea and ribbon clays in Denmark dated to about 860 yrs. B.C. /25/. The first mentioning of the fact that during the 8th century B.C. the geomagnetic field in Greece and Italy was oppositely directed to that of the present had been given in /27/. The existence of this excursion should be checked carefully in particular because of the fact that in the Holocene other separate excursions different in age revealed.

   Three excursions are clearly outlined during the Pleistocene. Recently within the time-interval of 50 - 100 thousand yrs. three geomagnetic excursions were discovered additionally /24/, but they have not been confirmed by other investigations up till now.
2. Gothenburg excursion. Palaeomagnetic anomalies dated to 11 - 13 thousand yrs. firstly described in Sweden /23/ have been recorde later by different authors in different sites and regions in marine and continental sediments of the northern hemisphere. Because of the absence of anomalous declination and inclination variations in some well investigated sections with high time resolution in North America and western and northern Europe the reality of a field excursion during that time has been called in question. On the other hand several other records of remarkable changes of declination and inclination reported from North America, Europe, middle and eastern Asia seem to confirm a real field excursion between 11 - 13 thousand yrs.
3. Mono Lake excursion was investigated in detail in the MonoLake section in California /21/ and was confirmed later in sections of the Tahoe Lake, California /26/ and by numerous other records from more than 50 sites of both hemispheres. This excursion is fixed in all regions investigated palaeomagnetically and documented in detail.
4. Kargapolovo excursion. This excursion is investigated in detail in sections from the southern part of western Siberia /8/, from the European territory of the USSR

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from the Indian Ocean, from Iceland and from a number of other sites; its age is determined as about 42 - 44 thousand yrs.
The duration of Late Pleistocene excursions is estimated as about 10^3 yrs. As a rule, these short excursions are marked by at least 2 - 3 large direction changes with reversion to the stationary field. In the southern Ukraine and in Moldavia series of excursions were discovered in the time-interval of 10 - 45 thousand yrs. It appears that some of them are restricted to distinct regions /4/. Such records could be explained as follows: I the sequence of a section is interrupted by erosion or sedimentation gaps and those gaps coincide with the stationary geomagnetic field, than on the background of the reduced section thickness each of the fixed swings corresponding to a short change of the field directions could be considered as a separate excursion.

Four to five excursions are discovered in the Middle Pleistocene. They are recorded in USSR within sedimentary series containing the Khazarian fauna.

5. Blake excursion. This excursion is examined in detail using bottom sediments from the Caribbean Sea, the Atlantic and the Indian Oceans /28/, in a core from a boring in southern Italy /16/, in sea and continental deposits of the Pricaspian and Povoljie, USSR /5/, in continental deposits from the southern part of Western Siberia /12/ and from many other sites. It is named after the Caribbean submarin Blake Outer Ridge /28/ where reversely magnetized deposits referring to this time-interval have been revealed for the first time.
In accordance with a number of data the Blake excursion is characterized by 2 - 3 swings with achievement of the field of opposite direction up to complete reversal. Compared with other Late Pleistocene excursions the Blake excursion is longer by an order of magnitude.
During the time-interval of 100 - 150 thousend yrs. excursions were discovered at more than 100 sites distributed over the globe. In some sections 2 - 3 excursions were fixed. The geographical distribution reaches from the equator to 70° n. lat. and over the whole northern hemisphere (fig. 1). Some records are from the southern hemisphere as well: from Australia, Indonesia, from the deposits of the Indian, Atlantic and Pacific Oceans. The manifestation of them envelopes not less than 50 % of the Eart's surface indicating their global or at least large-scale regional nature. It should be emphasized, that during reversals the non-dipol geomagnetic field envelopes areas of the same scale /11/.
6. Biwa I excursion. This excursion was studied carefully in bottom sediments of Lake Biwa, Japan /19/ and was dated to 176 - 186 thousand yrs. When examining the Biwa I excursion we suggested to join this excursion with the Jamaica excursion dated to about 210 thousand yrs. Both excursions are positioned close in time and in some sections are fixed as independent ones, whereas in others only single excursions were recorded. Registrations of these excursions are much less numerous than the Blake excursion records (fig. 1).
7. Chagan-Dniepr excursion (about 270 thousand yrs.) and Biwa II excursion (about 295 thousand yrs.). Records of the Chagan-Dniepr excursion are not less numerous than those of the Blake excursion. This excursion was registered for the first time in deposits of the Chagan river valley in the Gorno-Altai /2/. This excursion is recorded in all the regions explored by the Soviet scientists, on the whole at 76 sites over the Earth's surface. Both excursions are registered within the USSR in four regions: in sections of the Ukraine and Moldavia, in the Caucasus, in Middle

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Asia , in the southern part of West Siberia. The Biwa II and the Chagan-Dniepr excursion are very close in time, the difference is less than 25 000 yrs. Therefore it could be suggested that they are the manifestation of the same field event; the difference in time could be described to dating errors. But records of both the Chagan-Dniepr and the Biwa ii excursions testifies either the existence of two independent excursions of different duration or the occurence of one excursion but with rather a complex structure.

8. Biwa III excursion. This excursion is fixed and studied in bottom sediments of the Lake Biwa, Japan, and is dated to about 360 thousand yrs. /19/. Previously, it had been traced in oceanic bottom and continental deposits in Siberia /12/ approximately in the same time-interval but it had not been named. The age of the Biwa III excursion is estimated approximately assuming a uniform sedimentation rate. The existence of this excursion is revealed at more than 40 sites over the Earth's surface. The data on this excursion are obtained bypalaeomagnetic investigations of sedimentary rocks and lava flows.

At the present stage of knowledge within the Early Pleistocene four excursions are outlined. In the USSR they all are traced in deposits containing the Tiraspolian fauna.

9. Emperor excursion. An excursion registered in deep-sea cores from the Pacific Ocean and the Caribbean Sea dated to about 410 thousand yrs. is named after the Emperor fault in the vicinity of the Hawaiian Islands. It is found at 33 sites in different regions of the globe according to palaeomagnetic information from rocks of different genesis and indications from the interpretation of the linear marine magnetic anomalies /33/. The age of the Emperor excursion is re-examined continuously and now it falls in the range from 390 - 490±50 thousand yrs., being stratigraphically associated with the end of the Early Pleistocene. The Emperor excursion is longer than the others. Its duration, similar to that of the Biwa I excursion reaches 10 thousand yrs.

10. Elunino V excursion. The name of this excursion is associated with a section near the v. Elunino in the south of West Siberia. It is traced at other sites of the USSR distributed over a large area and recorded at more than 20 sites over the golbe. At Prichernomorie the Ureki I excursion corresponds in time to the Elunino V excursion. Age determinations using the mean sedimentation rates from different sections span the range from 390±50 - 490±50 thousand yrs. with a mean of 470 thousand yrs. At present, as the estimates of age are not accurate enough, it is impossible to decide whether the Emperor and the Elunino V excursions are two events of the same field anomaly or they represent two independen facts. However, the presence of both excursions in the sections /1/ seems to confirm their independence.

11. - 12. Elunino VI and Elunino VII excursions are named as the Elunino V excusion after the section located near the v. Elunino in south-western Siberia, where these three excursions are recorded. They were confirmed by other records in sections distributed over a vast territory of the South of West Siberia in sediments containing the Tiraspolian fauna. Excursions time-equivalent to the Elunino VI and VII excursions are registered at 20 - 30 sites distributed over the globe, among others in Italy /16/. The age estimations for these excursions (about 560 and 620 thousand yrs. respectively) are rather inacurate and should be inevitably changed and improved in the future. Each of both excursions is shorter than the Emperor excursion.

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In our review we have considered the sequence and time-characteristic of excursions of the Brunhes chron geomagnetic field of normal polarity. A similar field pattern is peculiar for the Matuyama chron geomagnetic field af reversed polarity.

Summaring those said above, the following main conclusions are to be suggested:

1. During the Brunhes chron not less than 12 excursions are observed, which agree rather well with the scheme based on the Soviet investigations (compare the paper of Pospelova, this monograph) as well as with the previous scheme of the Brunhes chron scale /15/.
2. According to their duration excursions can be distinguished for two categories of possibly different origin:
   a) Excursions not longer than 10^3 yrs. It seems, that not all excursions of this typeof the Brunhes chron had been discovered up till now.
   b) Excursions with a duration of about 10^4 yrs. as the Blake and Emperor excursions, which are indicated by linear marine magnetic anomalies too. Coinciding nearly with the end of the Elsterian/Okan glaciation and the Eemian interglaciation respectively they mark essential boundaries of the palaeoclimatic sequence of the Middle and Late Quaternary.

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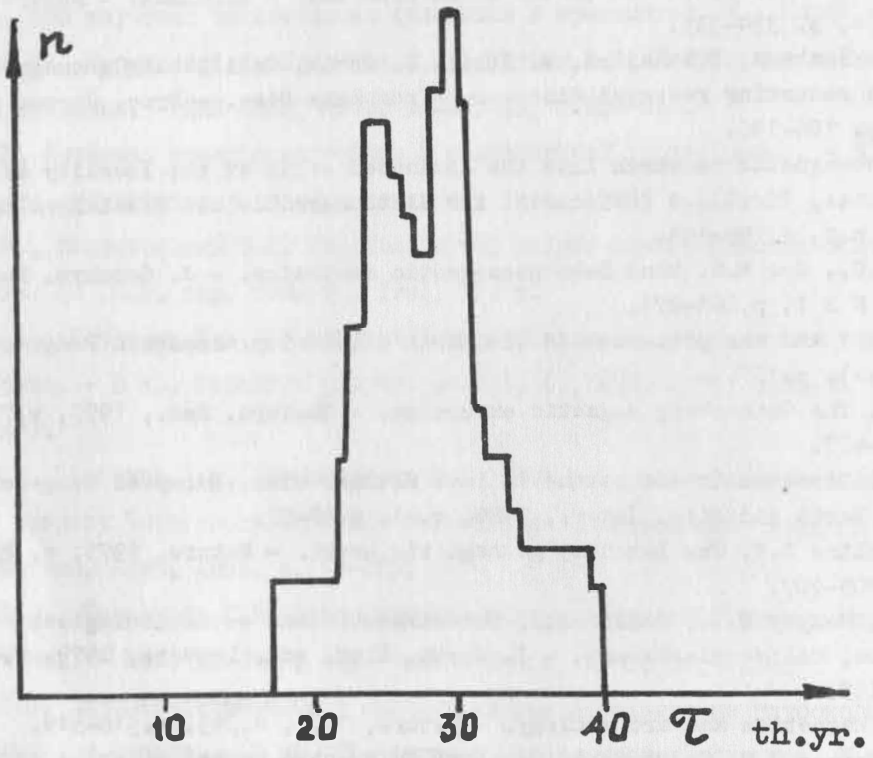

Fig. 2. Histogram of time-distribution of the excursion quantity during the last 20 - 40 thousand years in correspondence with the world data and proper weights (or reliability) of each definition.

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CATALOGUE OF PALAEOMAGNETIC DATA OF THE TASHKENT EXPEDITION (1982) OF THE COMMISSION OF THE ACADEMIES OF SCIENCES OF THE SOCIALISTIC COUNTRIES FOR PLANETARY AND GEOPHYSICAL RESEARCH (KAPG)

V.N. Vadkovskiy
World Data Center B2, Soviet Geophysical Committee of the USSR
Academy of Sciences

Palaeomagnetic data received by the treatment of the sample collections of Quaternary depositions in the Tashkent region are stored in the World Data Center B2 in tabular form as accepted by all participants of the expedition.

These data are made suitable for electronic data processing and for electronic data storage on magnetic tapes. The catalogue consists of uniform records being equal in length. Each record (line) includes the code of the author's name, the code of the section and the method of the magnetic cleaning (e. g. by electromagnetic fields, by heating, by temporal sample storage in or against the direction of the geomagnetic field).

Preparing this catalogue control programs, tests on permissible limits, programs for field smoothing were elaborated.

Selecting necessary data sets is enabled by adequate key words. The catalogue and all its software complements are open to be used for all participants in the project 2 of the Commission of the Academies of Sciences of the Socialistic Countries for Planetary and Geophysical Research (KAPG).

The catalogue of excursions of the Brunhes chron

In the catalogue of excursions of the Brunhes chron the following parameters are recorded:

1. Author, paper, year.
2. Location where the palaeomagnetic anomaly (PMA) had been recorded: district, section, co-ordinates φ, λ.
3. Thickness of the section containing the PMA.
4. Number of PMA within the section.
5. Rocks piling up the section.

5a. Rocks piling up the PMA.

6. Number of samples referring to the related part of the PMA.

6a. Number of cubes being within the level of PMA.

7. Dimension of cubes.
8. Thickness of the PMA part.
9. Methods for the investigation of the natural remanent magnetization (NRM) and other investigations (components of the magnetic mineral fraction, tests of redeposition etc.).
10. Age of the excursions.

10a. Other excursions comparable with the recorded one.

11. Duration of the excursion.
12. Methods for the determination of the age of the excursion.
13. Magnetic cleaning; declination D, inclination I, intensity Jn, Königsberger ratio Q (in case of sample collections in different levels than representation as tables counting the positions from the top).

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14. Mean trend values of declination D_m, inclination I_m, magnetic intensity Jn_m, Königsberger ratio Q_m before and after the excursion.
15. Maximum amplitude of the fluctuation of the excursion related to the trend field.
16. Virtual geomagnetic pole VGP of the excursion, co-ordinates of the recorded excursion Φ_{exc}, λ_{exc} and ovals of confidence.
17. Character of movement of the VGP during the excursion (description, preferably illustration).
18. VGP positions before and after the excursion, Φ, λ, α_{95} or θ_1, θ_2.
19. Field intensity during the excursion.
20. Method for the determination of the geomagnetic field intensity.
21. Reliability of the separated excursion (possible cause of its origin and its quality).
22. Comparison of the excursion with other geological and geophysical phenomena.
23. Remarks.

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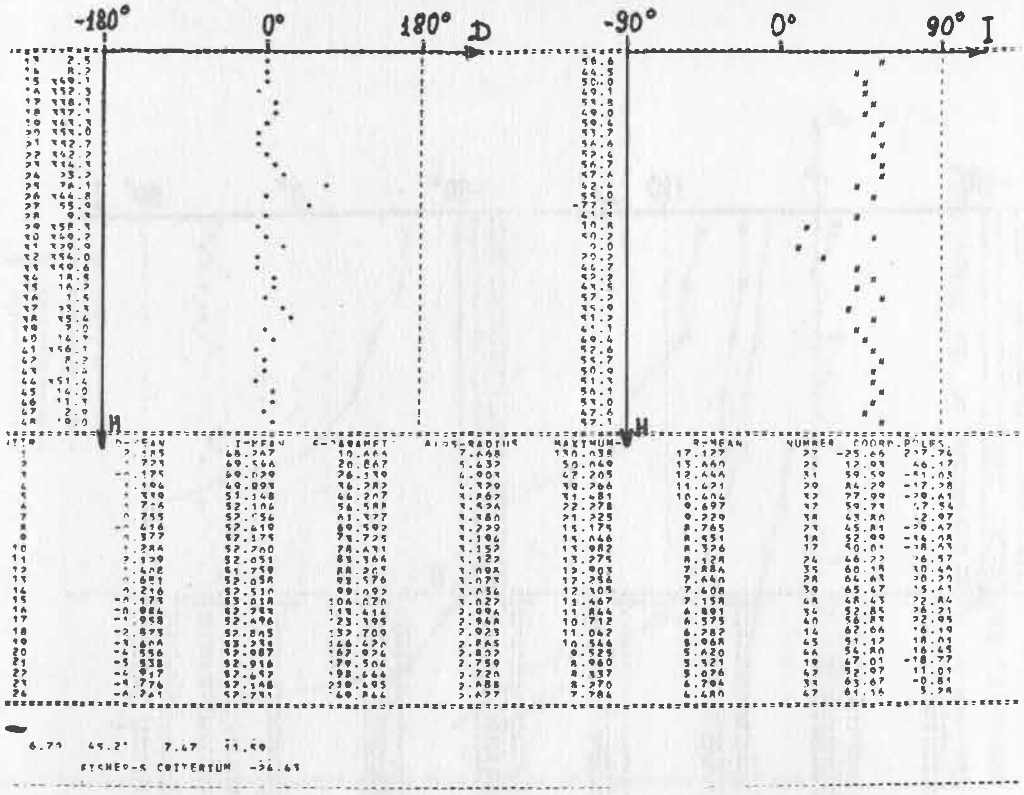

Fig. 1a.

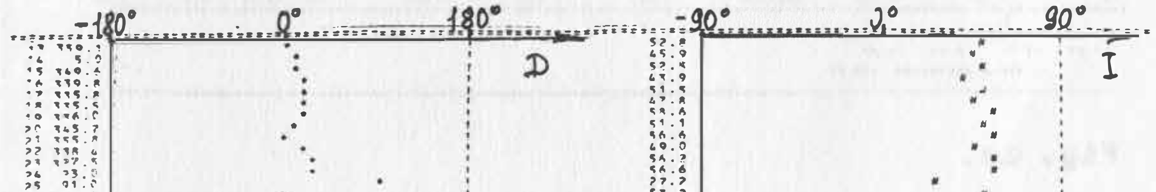

Fig. 1b.

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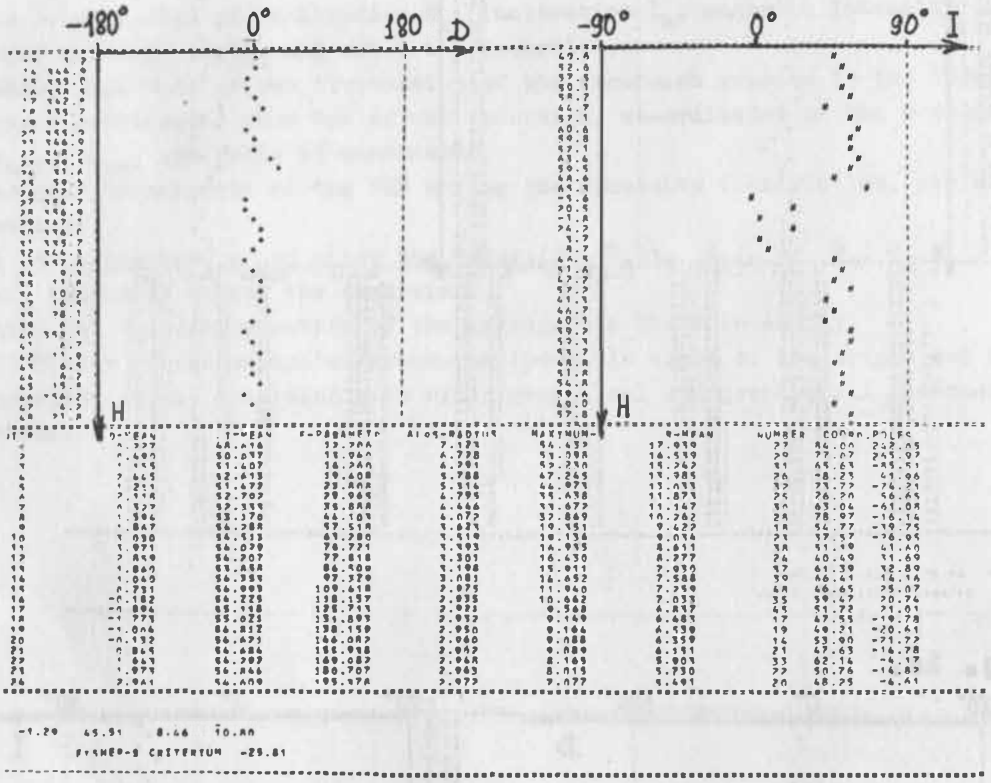

Fig. 1c.

Fig. 1. Scheme of variations of declination and inclination along Yangiyul section by P.Marton's data. H - depth in arbitrary units.
Left columnes contain values D and I in degrees.
a - in situ,
b - after cleaning alternative field 400 Oe,
c - after time-cleaning (one month, zero field).

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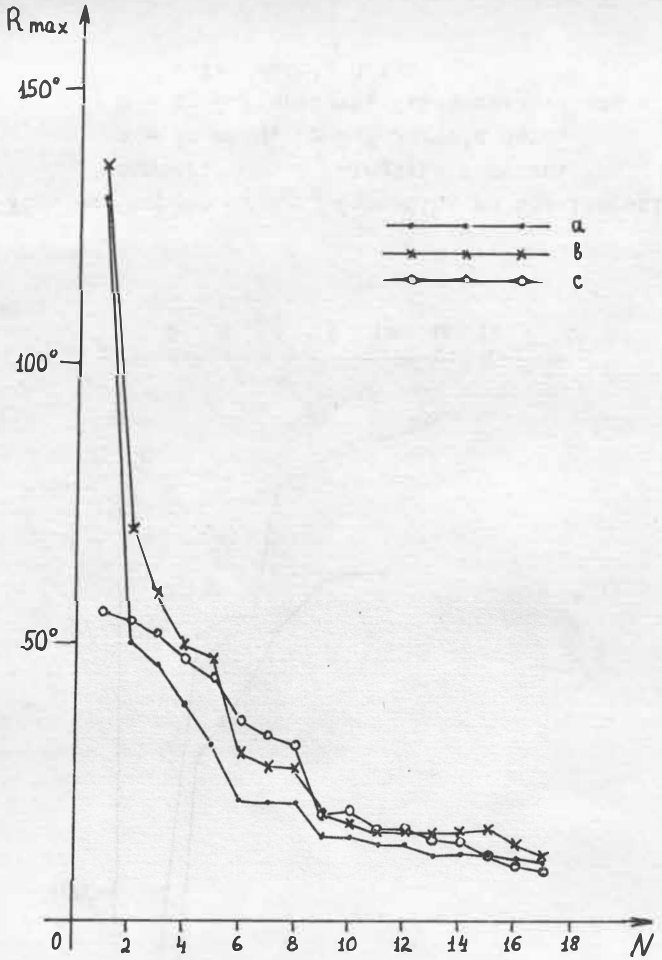

Fig. 2. Changes of the maximum distance of the points from mean values in depending on the number of iteration. Yangiyul section, by P.Marton's data. a,b,c - the same as fig. 1.

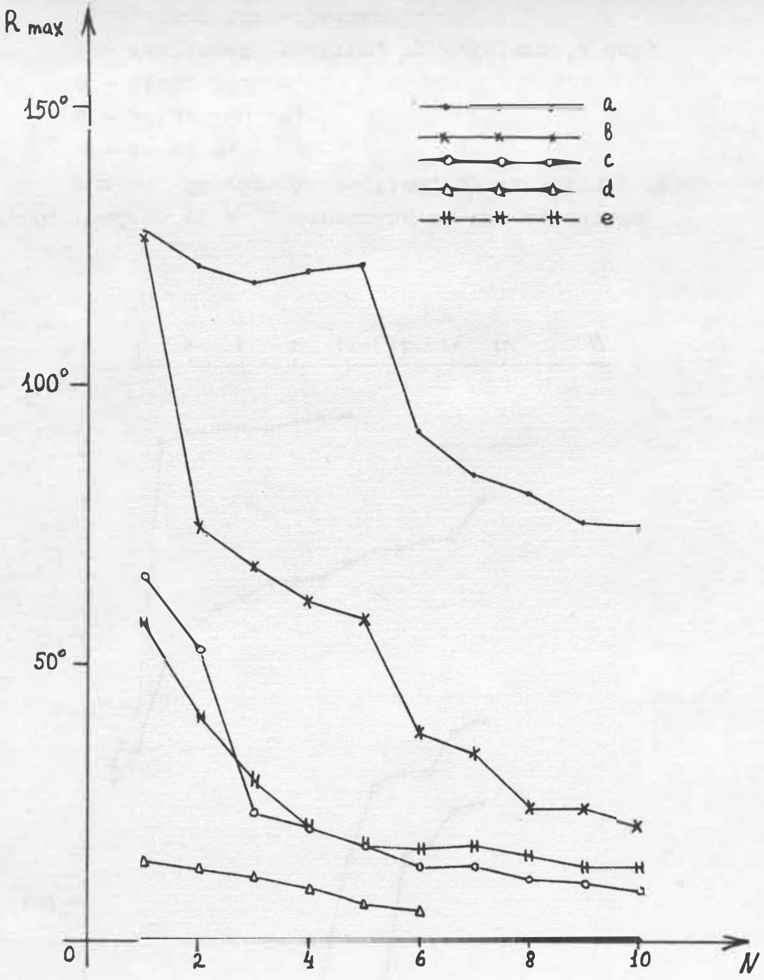

Fig. 3. Changes of R_{max} depending on the iteration number N. Karasu section.

a - by P.Nojarov's data,

b - by P.Pagač's data,

c - by F.Wiegank's data,

d - by P.Marton's data,

e - by J.Horaček's data.

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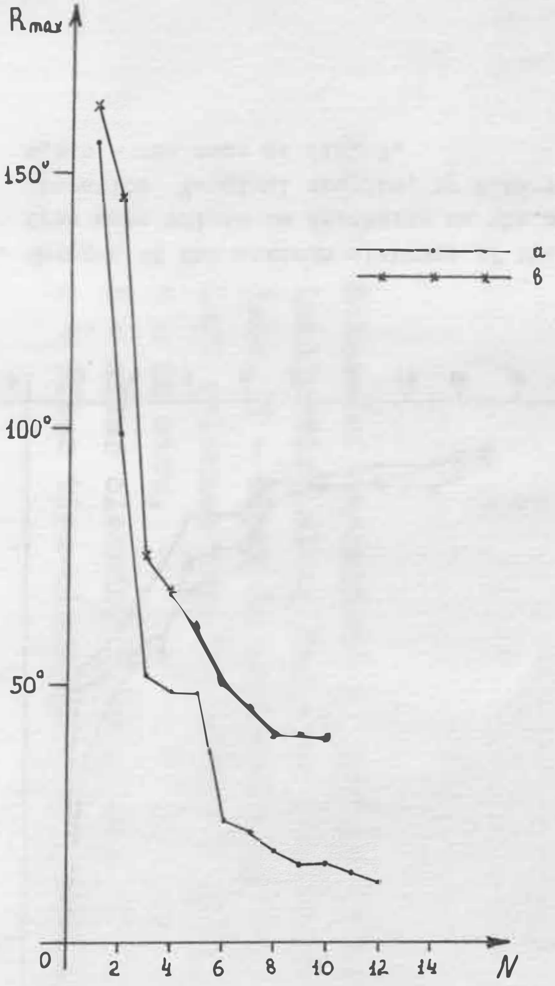

Fig. 4. Changes of R_{max} depending on the iteration number. Mingtepe section.
a - in situ, by P.Nojarov's data,
b - by G.Pospelova, V.Scherbakova and V.Yerjemin's data.

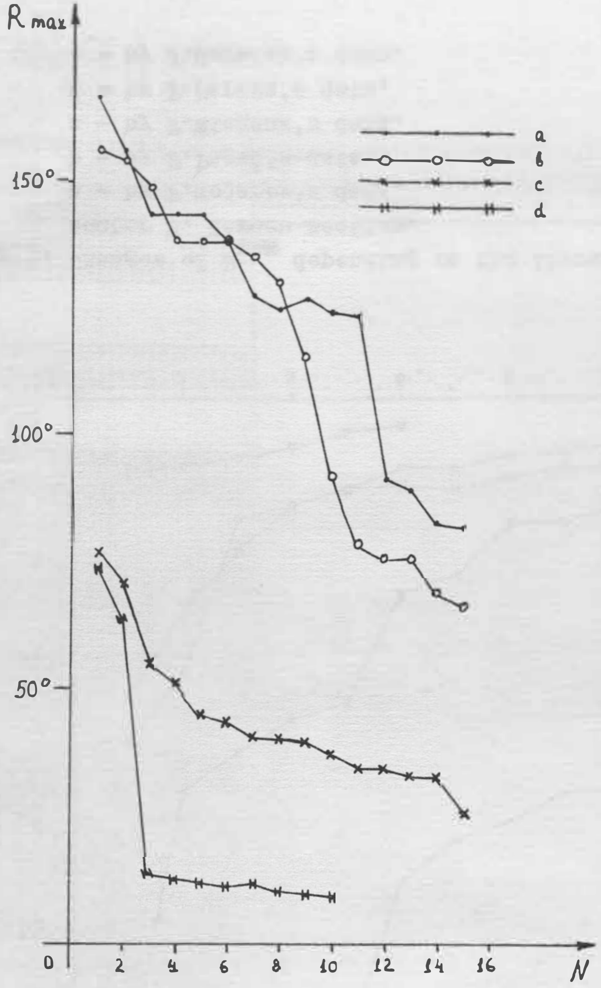

Fig. 5. Changes of R_{max} depending on the iteration number. Chernavoda section, by P.Marton's data.
a - in situ,
b - after 200 Oe,
c - after 500 Oe,
d - Kostinesti section, by P.Nojarov's data (after time-cleaning).

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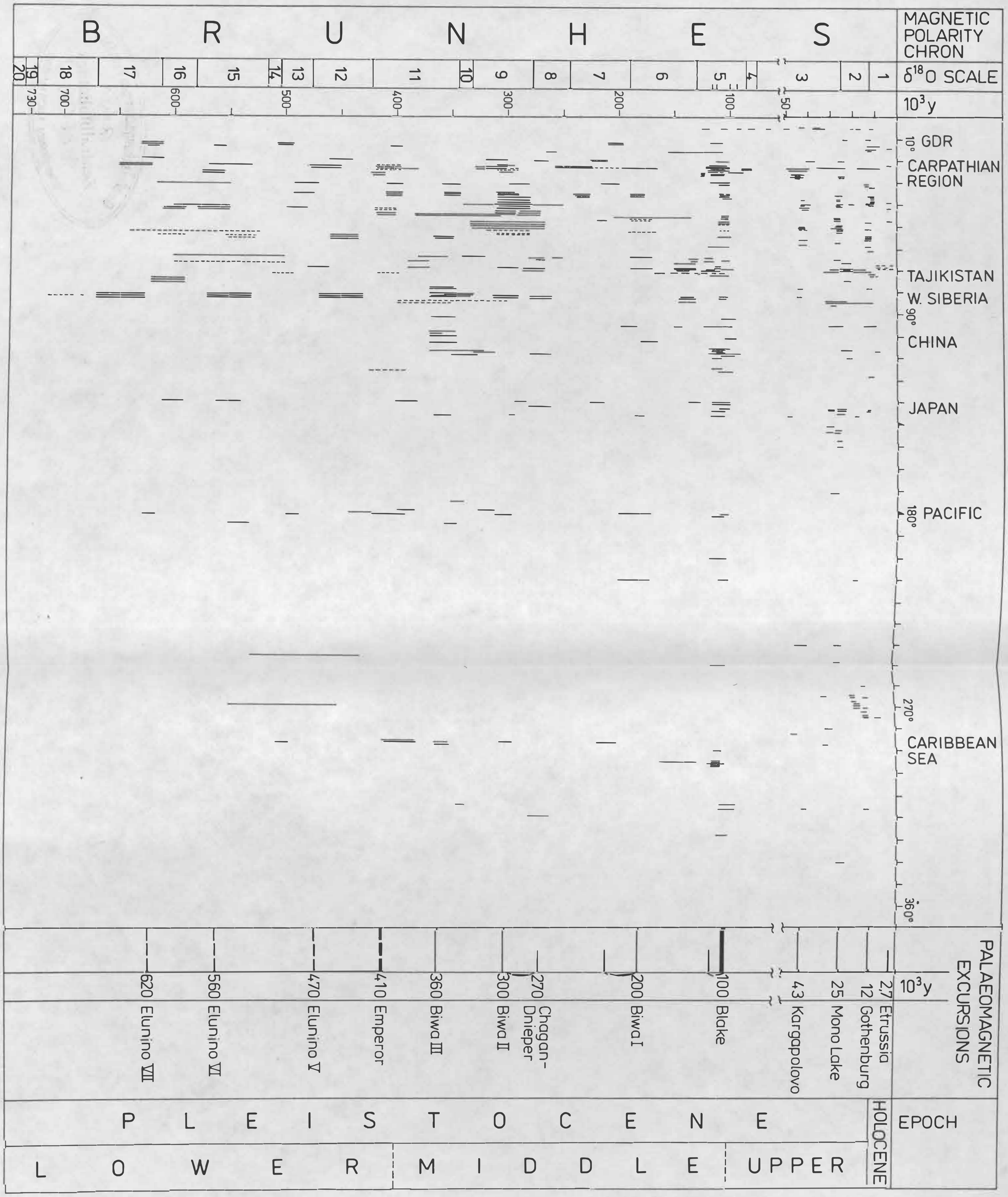

F. Wiegank et al.: Magneto-chronostratigraphic Scale Model, Brunshes Chron

Fig. 1. Summary of the geomagnetic field excursions during the Brunshes chron and the model of magneto-chronostratigraphical scale for the last 700 000 years.

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